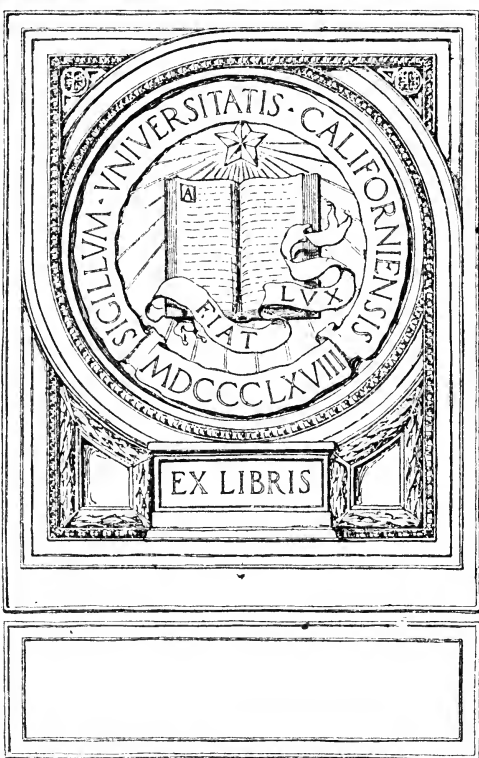


THE MANUFACTURE OF PAINT

J. CRUICKSHANK SMITH, B.Sc.

SECOND REVISED EDITION





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A PRACTICAL HANDBOOK FOR PAINT
MANUFACTURERS, MERCHANTS, AND
PAINTERS

BY
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TECHNICAL CHEMIST AND CHEMICAL ENGINEER

SECOND, REVISED AND ENLARGED EDITION
WITH 80 ILLUSTRATIONS

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PREFACE.

TWELVE years is no inconsiderable period in the history of any industry. In the paint industry, which is affected by mechanical progress no less than by chemical and technical evolution and discovery, such a length of time marks not a few changes in manufacturing methods and in the products obtained by them.

In this revised edition of *THE MANUFACTURE OF PAINT* (the first edition of which was published in 1901) the original scheme has been followed in the main, but the subject-matter has been revised throughout, and such additions and alterations have been made as progress and changed circumstances demand. For example, the developments which have taken place in the manufacture of mixed paints and enamels have necessitated the inclusion of a section dealing with this branch of paint technology.

No attempt has been made to provide recipes and manufacturing formulæ. To have done so would have altered the nature and intention of the book. The aim of the author has been to set forth in language as simple and concise as the subject permits the fundamental principles involved in the manufacture of modern decorative and protective paints, an industry which shows no signs of decreasing in importance in the near future.

The element of plant and machinery is so impor-

tant that prominence has again been given to it, and in this connection the author desires to express his obligations to well-known paint machinery experts, notably Mr. F. W. Follows and Mr. J. R. Torrance, for many helpful suggestions.

LONDON, *November*, 1914.

PREFACE TO THE FIRST EDITION.

ALTHOUGH there are several excellent treatises on the manufacture of Dry Colours or Paint Pigments, the author of the present volume while engaged in the manufacture of paint had frequent occasion to remark on the absence of a systematic, scientific and fairly complete handbook or guide to assist the paint-maker in accomplishing his purpose. The want does not appear to be peculiar to this country or to America, for inquiry elsewhere, more particularly in Germany and France, has failed to discover the existence of such a manual. The present volume aims at presenting in a connected and strictly practical manner the principles which are involved in the manufacture of the paints commonly used by the painter and by the decorator, an industry that forms no insignificant portion of British manufactures and exports. Nor does there appear to be any sufficient reason why our manufacture of paints should not be considerably increased to meet the growing requirements of the empire and of other countries if manufacturing operations are conducted on sound principles, and if due care is taken to produce an article precisely adapted to the wants of the customer, whatever these may be, conditions of climate, and all other incidental circumstances of each case being taken into account in the specification. Indeed, the opinion may be hazarded that in these days of reconstruction and readaption of commercial enterprises, there are probably few more hopeful fields for the application of honesty, scientific insight, and the practical skill which grows out of experience.

Machinery is an element of such importance in paint-making that it has been deemed proper to enter pretty fully into mechanical details, and to introduce numerous illustrative diagrams. Care has been taken to make the illustrations accurate and reliable; and in order that each diagram may be easily understood and may be effectual for its immediate purpose, it has not been loaded with details that are unnecessary for that purpose.

Chemical principles also enter largely into the manufacture of paint. In dealing with this part of the subject no attempt has been made to dispense with the ordinary terms and formulæ of chemistry. To have proceeded otherwise, and to have used only popular language, might have suited some readers, but would have been essentially misleading. At the same time, pains have been taken to render the exposition of the chemical principles that require attention as intelligible as possible to the untrained or partially trained reader.

While the present volume is intended for the use of paint-makers more especially, its contents may have some interest for dealers in the article and for painters and decorators. It is hoped also that it may be found to contain information and suggestions which may be serviceable to architects and contractors, and to companies and individuals who require paint in considerable quantity.

The author desires to express his obligations to several friends who have placed at his disposal information which has been of value to him in the preparation of this manual, acknowledging in particular the kindness of Professor Edmund J. Mills, F.R.S., Glasgow, and of Messrs. Follows & Bate, Ltd., Manchester.

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PART I.

CHAPTER I.

SCOPE OF SUBJECT AND DEFINITION OF TERMS.

THE manufacture of paint, regarded as a specialised branch of chemical industry, is comparatively modern in its development. In reality it is the outcome of a number of separate industries, trades and crafts. The word *paint* is used in the following pages to indicate material which is in a form suitable for application to a surface. Although this course has been adopted for the sake of clearness and uniformity, it is right to state that the term "paint" is still applied by some to mixtures of pigment and fluid medium which require to be diluted or thinned with a vehicle before they can be applied to a surface. Such materials are the products of the important and historic industry of *paint grinding*, and they will be referred to herein as *paste-paints*. Even dry pigments are still sometimes referred to as paints, but this practice is rapidly dying out.

Paint (to use the word in the sense we have indicated) implies the presence of a solid portion which we shall refer to as the *pigment*, and a more or less liquid portion to which the term *medium* may conveniently be applied.

The principle of specialisation in particular directions has long been a characteristic of the group of industries with which we are dealing. Thus it happens that certain manufacturing firms confine their attention almost exclusively to the preparation of the pigment, while others occupy themselves entirely with its transformation into paste-paint.

Many manufacturers, specialising still further, are concerned particularly with the production of a single pigment, or of one class of pigments. The manufacture of whitelead forms practically an industry by itself; the preparation of various grades of oxide of iron pigments constitutes the main part of the production of many firms; others direct their attention specially to the preparation of the finer sorts of chemical and lake colours. In like manner the paint manufacturer is a specialist, and the problem which forms the keynote of his work is to transform the dry pigment prepared by the colour maker into a material which, by reason of its physical and chemical properties, can be conveniently and successfully handled by the person who desires to apply it to a particular surface.

In order to accomplish this in a practical and at the same time a scientific manner, the paint manufacturer must possess not only an intimate knowledge of the principles and general rules that govern the mechanical processes usually designated by the term *paint grinding*, but also an acquaintance with the composition and the properties—chemical and physical—of his raw material. Furthermore, since it is part of his business to convert the product of the paint-grinder into a form in which it can be used by the painter, he has a still more complicated task, inasmuch as he must possess expert knowledge of the nature and function of the ever-increasing number of mediums with which the paste-paint can be admixed, and finally (a point the importance of which cannot be overstated) he must have an accurate appreciation of the requirements of the ultimate user of the paint.

It does not follow from this that the paint manufacturer must of necessity be an expert colour maker (indeed in many cases he cannot hope to be so), but he should at least be cognisant of the principles underlying the preparation of the various classes of raw material with which he has to deal. Knowledge of this kind places him in a position to

apply scientific methods to the transformation of raw material into paint suitable for use under varying conditions.

Paint making depends partly on chemical and partly on mechanical principles; therefore a knowledge not only of the chemical composition but also of the physical properties of pigments is necessary in order that full justice may be done them in the paint manufacturing process. An accurate knowledge of the physical properties of pigments—for example, size of particles, specific gravity, and the like—is probably less common among paint makers than might be expected. It cannot be disputed however that such knowledge, along with an acquaintance with what may be termed the *large mechanical operations* of colour making, such as dry grinding, levigating, precipitation, filtering and artificial drying, materially assists the paint maker in dealing with the problems that present themselves from day to day in every paint factory of importance. For example, the differences that may be observed during the grinding in oil of two samples of oxide of iron can often be explained if the process of manufacture through which the pigments have passed is known, and its special peculiarities in each case appreciated. In fine, if the paint manufacturer who does not happen to be also a manufacturer of the pigment is possessed of the knowledge here referred to he will be able, by watching the behaviour of the pigment in his hands, to fasten quickly and with confidence on any signs of adulteration or of faulty mechanical preparation.

No attempt is made in the present volume to treat in an exhaustive manner of the preparation of pigments. This forms a highly technical subject by itself, just as varnish making constitutes a collateral industry. Nevertheless, the operations involved in the preparation of pigments are so closely connected with the particular industry which is engaging our attention that the following general commentary on matters which may be described as lying on the borderline of paint making may suggest lines of study and

inquiry among those who are engaged in the last-named industry.

Dry Grinding or Powdering.—Pigments which have to undergo a process of grinding to render them fit for the paint maker's use belong largely to the highly important classes usually referred to as *iron oxides* and *earth-colours*. Many such pigments are obtained naturally in a state of sufficient purity to enable them to be used for paint making after being reduced to a suitable degree of fineness by the simple process of dry grinding, which may or may not be followed by sifting.

Sifting.—This process follows naturally from the dry-grinding process already referred to. An examination of any dry-ground material will show that the particles composing it are of various sizes. When coarsely powdered material has been reduced in an edge-runner, the only practically efficient method of separating the coarser particles from the finer is by the adoption of a system of screening or sifting. This can be accomplished by passing the ground material through a special sifting mill, furnished with screens of wire gauze. It is obvious, however, that such a method of separation is based entirely on the difference in size of the particles, and does not affect the composition of the product at all. In other words, the finely ground pigment is of the same chemical composition as the raw material, and contains the same proportions of the various components, whether harmful or otherwise.

Wet Grinding.—Materials of complex composition, which contain components that are detrimental to the pigment, *e.g.*, silica, are frequently ground under water by heavy machinery of the flat-stone or edge-runner types. The process is known as wet grinding, and is followed by *levigation* or *floating*, the object of which is to separate by means of their different degrees of buoyancy in water such diverse ingredients as silica, argillaceous earth and oxide of iron. Ochres, umbers, siennas and native oxides of

iron are usually "refined" in this way before they are offered to the paint grinder, and a great deal of the enhanced value of a levigated pigment is due to the elimination of silica and to the production of a pigment whose particles are small and uniform in size. By using a finely levigated pigment the paint grinder will effect considerable saving in respect of wear and tear in his grinding plant, and he will also produce a much better paste-paint than he would do if he used a dry-powdered pigment.

Pigments that have been levigated should be examined for moisture, as the drying appears in many cases to be conducted in a very haphazard way.

Frequently dry-ground pigments fail to give entire satisfaction to the paint grinder, because he finds that, however finely a material may be powdered, it is liable when worked up with oil to produce a spongy paste-paint. The difference observable during the grinding in oil in the behaviour of pigments which have been ground and separated in the wet way, and of those which have been dry-ground, is usually traceable to one of two causes. The first of these is that the dry-ground pigment is less amorphous in structure, and there is greater variation in the size of the particles. This results in the paste-paint also containing particles whose size varies through wide limits, and the paint consequently lacks coherence. The second reason is that a dry-ground pigment usually contains the same proportion of silica and other indifferent paint-forming substances as did the original material, whereas in the wet-ground and floated pigment these deleterious ingredients have been washed out. For similar reasons finely levigated pigments remain in suspension in mixed paints better than dry-ground pigments.

Precipitation.—Many pigments are produced surrounded by a large excess of water in accordance with the ordinary methods of precipitation. The chromes, Prussian blue and Brunswick green are instances. Technically therefore these

are after precipitation comparable with pigments which have undergone levigation, but with this difference that the separation to be effected is not in this case between particles of varying size and composition, but between particles of comparatively uniform size and composition and water, the latter containing in solution sundry substances which must be eliminated from the finished pigment.

Washing.—This process is essential to the freeing of pigments prepared by certain chemical methods including precipitation from soluble impurity. Many pigments produced by methods in which precipitation from aqueous solutions plays no part have to undergo washing, and imperfect treatment in this respect will be sure to cause the paint grinder trouble. Thus whitelead is ground in water and washed to free it from traces of acid and unconverted metallic lead. Certain grades of barytes also after being dry-ground are subjected to an acid treatment to remove traces of iron and to improve the colour. This involves subsequent washing. Originally washing consisted in agitating the material to be treated with successive quantities of clean water, allowing the solid matter to settle, running off the supernatant liquid, and repeating the process again and again till every trace of soluble impurity had been eliminated. This decantation process is still adopted in many departments of colour making, as in the washing of chromes, Prussian blue and lakes.

In the case of large masses of material which it is desired to free from traces of soluble impurity, washing on the large scale may be effected by a modified water floating apparatus consisting of a series of tanks or similar receptacles of suitable size. The material to be washed is placed in the first, and a stream of water admitted. This tank overflows into a second, and the latter into a third tank, and so on. Portions of the solid material are of necessity carried over with the effluent, but the stream of water is so regulated, and the size of the respective tanks so arranged, that

in the end practically water only passes out. When the effluent is found to be free from soluble impurity, the water pressure may be increased so as to wash the bulk of the contents of the various tanks into the last one, whence they are transferred to the filter press and finally dried. The introduction of the power filter press, and the gradual improvement in the mechanical details of this essential part of the modern colour maker's plant, have to a great extent revolutionized the process described above, filtering and washing being now frequently conducted at the same time. Imperfect washing in the case of chemical colours leads to grave trouble when they are ground with oil.

Filtering.—Simple filtering or draining, in which the material to be freed from water is placed upon a porous medium, so that the water gradually percolates away, is usually much too slow a process for modern colour works. Only in a few special circumstances is such a method applicable. The enormous improvements that have taken place in the construction and efficiency of filter presses have rendered the use of these pieces of plant practically universal.

In modern colour works practice washing and filter-pressing are conducted simultaneously, and there is sometimes a danger of the pigment containing minute traces of impurity. Numerous apparently obscure defects in finished paints have been traced to the presence of such minute traces of chemical matter in the pigment. This refers very particularly to lake pigments.

Drying.—The final process through which chemical pigments produced by precipitation, or pigments which have been washed or levigated, have to pass is that of drying. It is remarkable how the appearance and physical texture of a pigment can be modified by variation in the conditions of drying. A tough or friable or flinty or soft texture may be communicated to some pigments simply by altering the temperature and conditions of drying. The capacity of the

pigment to assimilate oil is also liable to be affected, and this is a point which is of vital importance to the paint grinder.

The great point for the latter to observe is to ensure that the physical properties of the pigments with which he proposes to deal are suitable for the purpose in view. Chemical composition may have to be considered, but physical condition is at least as important.

CHAPTER II.

STORING AND HANDLING RAW MATERIAL.

IN making adequate provision for the storing of the various materials in everyday use in the operations connected with paint making, two points may be noted as being of special importance. The first is the storing of the raw material in such a manner as to protect it against possible alteration and depreciation from external agencies. The second is the practical necessity for rendering the storage arrangements as convenient as possible for the rapid transference of the various ingredients to the machinery in which the manufacturing operations are to be conducted.

The varying nature of pigments necessarily involves that some are more susceptible than others to the influence of such agencies as heat, cold or moisture; consequently when large quantities of raw material have to be stored it is essential to provide means whereby the material can be kept at its normal standard of quality. If for instance we take dry whitelead, it is a well-known fact that the newly prepared pigment is less suitable for grinding into paste than the same material after it has been kept or aged for a certain length of time. In point of fact, chemical changes take place in the composition of the material itself, so that whitelead three months old is of a distinctly different composition from the bulk when freshly prepared. Moreover, whitelead is liable to deteriorate by being stored in a moist situation; the ageing process goes on more advantageously in a dry, cool, equable atmosphere.

Other pigments, principally those of a bulky voluminous

texture, offer great facilities for the hygroscopic absorption of moisture. Thus oxide of zinc and whiting, even when exposed to ordinary climatic influences, absorb sufficient moisture to injure their paint-forming qualities. Terra-alba or gypsum is a pigment which presents the same peculiarity, and has in addition a strong chemical attraction for water; special means have therefore to be adopted to ensure its remaining as nearly as possible anhydrous. There are on the other hand some pigments which are injured by too dry an atmosphere, especially when the dryness is accompanied by a temperature considerably above the normal. Certain lakes belong to this class, and their brightness and depth of colour is noticeably affected by the conditions alluded to. Thus it is seen that, by considering the nature and special requirements of his raw material when arranging for its accommodation, the manufacturer provides against depreciation and possible loss.

The advisability, not to say the necessity, of having all raw material, whether of the nature of pigment or of oil or other grinding or mixing medium, stored with reference to the maximum of convenience in charging paint mixers and mills, is almost too obvious to call for remark; yet one has only to pay a visit to some of the old-fashioned paint works to observe with how little regard to convenience and economy the raw material is frequently stored. A method which appears to be a most satisfactory one, and which has been adopted with success in several modern paint factories, is that by which the crude or raw material is at once elevated to the top of the building, and is then allowed to descend from floor to floor, passing through an additional process at every stage. In this way intermediate handling is reduced to a minimum. Probably the most marked difference between an up-to-date paint factory and an old-fashioned one is that in the former little is seen of the materials from the time they enter upon the manufacturing process at the top of the building till they emerge

in the finished state at the bottom ; while in the latter each operation forms a small manufacturing process by itself, and the materials have to be lifted by hand between each operation, to the great increase of the manufacturing cost charges on account of labour. It is impossible to make cut and dried suggestions as to the planning of a modern paint factory. The peculiar circumstances of each case must be taken into account. Except in cases in which ground space is very valuable or existing buildings have to be dealt with it is doubtful whether buildings of more than two floors are economical.

One factor which will influence to a great extent the planning of the works is the precise nature of the plant which will predominate. If the machinery be of a heavy type the nearer it is to the ground level the better.

The ideal goal to aim at is to have the process as nearly continuous as possible and to reduce wasteful handling to a minimum. Most works possess far too little tank room for oils and mediums, and there is often a lamentable deficiency in pipe lines from storage tanks to the grinding and mixing departments. Even old buildings and inconveniently arranged factories may by thoughtful rearrangement and wisely directed outlay be remodelled partially or wholly in such a way as to reduce materially the cost of production.

It is impossible to lay down any rule which can be uniformly adopted in the matter of arrangements for charging pug-mills and other mixing plant. The size and construction of the individual machines vary so greatly that a method which is excellent for one case is probably very unsuitable for another. This is a matter in which the paint manufacturer cannot always follow with blind confidence the advice of the maker of paint machinery, for the reason that it is impossible for anyone outside the paint trade to appreciate the differences in the behaviour of different paints and pigments which at every turn confront those engaged in the industry. Thus a feed apparatus which is suitable for

a dense heavy powder which does not readily fly about in the form of dust may be totally unsuited for dealing safely and efficiently with another material, the particles of which are exceedingly fine and tend to float in the air. In like manner an apparatus designed to convey unground paste from the mixing mill to the grinding rollers may perform its functions with success in the case of materials containing a large proportion of oil, but may be unsatisfactory with those of an exceptionally stiff texture.

An incidental advantage secured by good storage, whether of raw or finished material, is that efficient stock-keeping and stock-taking are promoted. The ability to take at any moment a prompt and accurate inventory of stock is a matter of the greatest commercial importance, and is impracticable unless a methodical system of storing is adopted. Quantities of dry pigment, up to say 20 cwt., are frequently conveniently stored in square bins. If the weight of the material which fills the bin up to a given height is determined, a simple calculation will indicate what weight of pigment corresponds to every inch of vertical height, so that by simply levelling the surfaces and determining the depth with a measuring rod the stock can be quickly estimated with sufficient exactness. Of all the packages in which pigments to be used for paint making are usually stored, those composed of bagging or sacking are probably the most unsatisfactory. Not only do they provide no protection against moisture, atmospheric or otherwise, but they are always liable to become torn or damaged, which leads to loss of material. When raw material has to be stored in this way, special provision should be made against depreciation and loss.

CHAPTER III.

TESTING AND VALUATION OF RAW MATERIAL.

A CLEAR distinction should be made between *valuation* and *analysis*. From the point of view of the man engaged in industrial processes, chemical analysis is only a means to an end, that end being to determine whether a material is suitable for a given purpose. In short, whereas analysis expresses certain results, technical valuation goes a stage farther and interprets these results. The expression *testing* is used in rather a vague way. For our present purpose, however, it may be defined as any method or process of examination of a substance which yields information regarding a particular property or group of properties possessed by that substance. Thus a sample of yellow ochre may be tested as to its suitability for use as a staining pigment without any analysis being necessary. At the same time a full and true appreciation of the technical value of the substance requires the combined information yielded by technical testing and chemical analysis. For example, in the case of the yellow ochre referred to, a slight adulteration with lead chrome, which might seriously detract from the value of the pigment for a particular purpose, could be detected only by strict chemical analysis.

Hence both the "tests" which the "practical man" understands and believes in, and the results obtained by the chemist, have their place and value and should be regarded as the complement of each other.

We may assume that nowadays every paint manufacturer of any standing retains the services of a trained chemist who is able to determine the composition of any ordinary material placed before him. Special training, however, and experience

in the paint industry are required by such an official in order to render his services of maximum utility to the paint manufacturer. To take a simple illustration, let us suppose that the composition of a sample of venetian red is expressed in the usual way—so much ferric oxide, so much calcium, so much silica, and similarly with the other ingredients. These results impart a certain amount of useful information, but their utility would be much increased if it could be stated with moderate certainty whether such components as calcium sulphate, barium sulphate, calcium carbonate, silica, etc., formed part of the native material or were present as added adulterants, and further, what probable influence the presence of these ingredients would exert on the manufactured paint.

On the whole, therefore, it will be seen that the analysis frequently required in connection with the materials used in the paint-grinding industry partakes of the nature of the proximate analysis so well known in commercial organic chemistry.

In connection with a few of the points worthy of attention in estimating the value of a given pigment, allusion may be made in the first place to *permanence*, which in this aspect may be described as the capacity to retain unimpaired those properties in respect of which the material is selected as a paint-base. Absolute unalterability under all conditions is a feature which it may be asserted no pigment presents, nor is it of primary importance in a pigment, provided that such alterations as the pigment is liable to do not affect prejudicially the essential properties of brightness of colour, protective capacity and the like. The permanence of a pigment may mean one of two things. It may mean the sum of those properties which render the pigment as a pigment proof against external agencies such as heat, moisture, light, common atmospheric gaseous impurities and the like; or it may mean the capacity of the pigment to retain its specific properties when associated with other pigments, and when mixed with various mediums to form

the material known as paint. Cases are known in which two pigments, each permanent in a definite degree as regards colour, materially affect each other's permanence in this respect when associated in the form of paint. Absolute permanence therefore is a highly desirable property, which however, like absolute insolubility in the region of pure chemistry, is attainable only in theory.

Another point which has a bearing on the value of a pigment is the mutual reaction between the pigment and the medium in which the pigment is ground or with which it is mixed. In the grinding of comparatively inert pigments such as zinc oxide or oxide of iron in a drying oil, any interaction that takes place is not of sufficient magnitude to call for special remark. In the case, however, of a complex chemical pigment or a lake, observation as to the action of the pigment on the chemically active drying oils, on turpentine, and on the resins, cannot be safely neglected. It is to be feared that rule-of-thumb still plays more than a small share in the *modus operandi* of paint making, and we must insist that if it be the object of the paint manufacturer to produce an article that shall possess in the highest degree those properties which render it most suitable for a specific purpose, it is by attention to points such as those now indicated that this result will be attained.

Having alluded to the analysis, whether qualitative or quantitative, and to the resulting valuation of pigments based on their chemical composition and properties, we have now to consider in some detail a system of valuation based on certain physical properties of pigments which are of great practical importance to the paint manufacturer. These properties are :—

1. Colour.
2. Opacity.
3. Tinctorial power.
4. Specific gravity.
5. Paint-forming properties.

Colour.—With the abstract question as to what is colour we are not now concerned. For our present purpose we may regard the colour of a pigment simply as a useful standard of value to the paint maker. This necessarily involves a limitation to the effect that only similar pigments can be compared in this respect. Thus, for example, we arrive at no practical result by comparing for purity of hue a sample of whitelead and a sample of oxide of zinc. But we can compare two or more samples of oxide of zinc and place them in order of merit so far as purity of hue is concerned. But it is necessary to go a step farther and to apply another limitation, which is that only similar colours, or similar shades of colour, can be compared in this way. Thus light Turkey red and deep Indian red are pigments of similar composition, but no quantitative result, so far as determining their respective value for paint grinding, is arrived at by comparing their colour. Take, on the other hand, a range of samples of either one or the other of the two pigments and the colour of the members of each series may legitimately be compared, and may serve as a guide with regard to the suitability or otherwise of the pigment for a specific purpose. The exact significance of the term "colour" when applied to the testing of pigments is exceedingly varied. Thus in the case of some pigments brightness or "fire" is sought for, in others depth and solidity of hue. An emerald green and a quaker green may each possess a rich and highly characteristic colour, but these pigments cannot be compared in respect of this property.

A point liable to be overlooked is that, if pigments are being compared for colour, the comparison should be carried out with samples of the pigments ground in equal quantities of the oil or other medium which is to be finally used in grinding and mixing on the large scale. That considerable differences in tint are manifested when the dry pigment is compared with another portion of the same pigment ground in oil, turps, or water might be expected, but without

practical experience one is hardly prepared for the surprising variation in the colour caused by altering the proportion or nature of the medium. In comparing samples of earth colours or of oxide of iron pigments special care should be taken that the quantities of oil and pigment are uniformly proportioned; and further, that the two are very thoroughly incorporated by means of a muller on a slab before the comparison is made. If a gritty pigment is in question the same amount of grinding must be given in each experiment.

Opacity.—This is one of the most important properties of pigments, and one which in certain classes of paint is likely to be the ultimate criterion of the value of the material to the painter. The popular term “body” when applied to paint usually expresses the same idea as opacity, and *hiding power* is an alternative name. It is a well-known fact that if various pigments are ground separately in linseed oil, and are then thinned out to suitable working consistencies, the opacity of the several samples of paint so prepared varies according to the nature and composition of the various pigments. A simple way of showing this is to paint films of as nearly as possible equal thickness of the various samples on a prepared white ground with black lettering on it. In the case of one paint, the ground and lettering may be almost entirely masked with one coat, and completely so with two, while with another paint three or even more coats may be required before the work looks “solid,” as the painter says. If it be permissible to deduce quantitative results from so crude an experiment, we might say that the opacity was inversely proportional to the number of coats required to obscure the ground-work entirely. A more accurate method of determining opacity is to prepare samples of paint using various pigments, to apply them to pieces of clear glass, and to observe the distance at which black letters on a white ground can be read through the films. The smaller the distance at which the type disappears from view the greater the opacity. In all

methods such as these, sources of error are numerous, and the errors may be of serious magnitude. To such an extent is this the case that many authorities maintain that in estimating opacity quantitatively the determinations must be carried out with the dry pigment. For this purpose a useful instrument is Mill's colorimeter, and the method recommended in using it is as follows:—

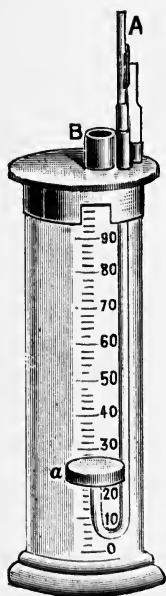


FIG. 1.—Mills' colorimeter.

A very small weighed quantity, say .5 gram, of the pigment under examination is thoroughly mixed with a large excess of linseed oil, or, in the case of very heavy pigments, castor oil, forming a turbid fluid, which is then poured into the colorimeter up to a certain mark. On the flat up-turned end *a* of the movable rod *A* is placed a small black disc—an ordinary shoe button is suitable. The rod is then pushed down into the turbid liquid till the black disc just disappears—the observer looking vertically down through the wide tube *B*. The mark on the side where the disc disappears is then noted. A similar experiment is carried out with a standard sample, of which the weight taken is varied during repeated trials till the disc is found to disappear at the same mark as in the case of the sample under examination. The opacity varies inversely as the weight taken. Let *W* be the weight of the standard, *W*¹ the weight of the sample, and let the opacity of the standard be represented by 100, then

$$\text{Opacity of sample} = 100 \frac{W}{W^1}.$$

It is important in comparing opacities by the method here described that the mean size of the particles of pigment in the different samples be as nearly as possible alike, otherwise a grave source of error will be introduced. A small

pan-mill driven by hand power or by electricity is a convenient adjunct to the laboratory for preparing samples for accurate determinations of this kind. It should be so constructed that the pan and the runner both revolve, but the latter, which should be small, should revolve much faster than the former, so that the friction between the grinding points may be as great as possible.

Tinctorial Power.—This property is also expressed by the term *staining power*. By virtue of their tinctorial powers pigments communicate, in greater or less degree, their own characteristic hue to such other pigments or paints as they may be mixed with. Tinctorial power is a property of the greatest importance to the paint manufacturer, and the special circumstances of the case will decide whether a given pigment should excel in this property as well as in that of opacity, or whether one of these properties is especially desirable, and if so which. For example take the case of such pigments as Italian ochre and burnt sienna. The main use of these materials is to communicate certain characteristic tints to white pigments—whitelead or other white base. Indeed the term *staining colours* which is popularly applied to the class to which these pigments belong indicates as much. The absence of opacity in these pigments is therefore not an important matter, but their value will depend to a great extent on tinctorial power. Staining or tinctorial properties are measured simply and expeditiously by mixing weighed quantities of the pigments it is desired to compare with a large excess of some suitable white diluent (whitelead being the one usually employed), carefully grinding the mixture in oil, water or other convenient medium, and comparing the tints so obtained. To gain a thorough knowledge of the tinting properties of a given pigment, it is well to note the tints produced by varying proportions of the diluting base, as some pigments cannot be satisfactorily compared as regards staining power until the dilution has been carried to an extreme limit.

The determination of the *tinctorial power*, *staining strength* or *reduction value* of pigments constitutes a considerable part of the daily routine work in the paint works laboratory, and any contrivance which will save time in connection with the numerous weighings which have to be made on chemical balances is to be welcomed provided no loss of accuracy is involved. The usual practice in determining the reducing value of a selected white base (white-lead or oxide of zinc as the case may be) on the coloured pigment under examination is to weigh separately portions of the pigment and the white base in the ratio of one part of the former to 10, 15, 20, 25, or 50 parts of the latter, grinding the mixture together in oil and observing the resulting hue in comparison with a standard prepared in the same way. It does not matter what the actual weight of pigment and white base may be provided the ratio between the two ingredients be definite and constant. The chief source of error in comparing the tinctorial powers of pigments is the practical difficulty of always correctly distinguishing between *tint* of colour and *depth* of colour. In other words, the intrinsic colour value of slightly different shades cannot be accurately measured by the eye. Ingenious and complicated methods have been devised to overcome this difficulty. Lovibond's Tintometer is an instrument which possesses merits in this connection, and although it is calibrated on an entirely arbitrary system it has been found extremely useful in measuring the colour effect of one pigment on another in various degrees of dilution. It is also not without value in comparing the opacity of pigments and the hiding power of paints. Other methods of comparing the opacity and hiding power of paints and pigments are now coming into use. Some of these are based on true physical measurements, and considerable advances have been made in this department of paint technics. As the apparatus is complicated and finality has not yet been reached, those interested in such matters are referred

to current scientific literature for further information on the subject.¹

Specific Gravity.—During the last few years much greater attention has been paid to the specific gravity of pigments than formerly. This is due in a great measure to the rapid advances which have taken place in the technology of mixed paints. The conception of "volume" in connection with these products is a comparatively new idea, but it is important and bears a close relation to the designing and manufacturing of these, the ultimate products of the paint manufacturer's skill.

The "relative weight" or "relative density" of different pigments are expressions which have often been used in an exceedingly loose way. Thus red lead and whitelead have often been referred to as heavy pigments, and since their specific gravities are usually over 8 and 6 respectively the description is not essentially incorrect. In popular paint language, however, barytes is also frequently described as a heavy pigment, although its specific gravity as a rule does not greatly exceed 4. On the other hand oxide of zinc has been described by people who ought to be well informed in such matters as a light pigment, notwithstanding the fact that a determination of its specific gravity proves the latter to be in the case of normal samples well over 5.

Many of these misconceptions are due to the rarity with which paint manufacturers trouble themselves about the less apparent physical properties of the pigments they use. If three kegs of equal capacity are filled in a casual manner with whitelead, white barytes and high grade oxide of zinc, the weight of the latter pigment contained in the keg will be considerably less than that of either of the two other pigments. But very elementary scientific investigation will

¹ *Vide* "Tests on the Opacity and Hiding Power of Pigments," by G. W. Thompson, "Jour. Indust. and Eng. Chem." Feb.; 1913, also "The Coating Power and the Hiding Power of Paints," by G. W. Thompson, "Proc. 8th Internat. Congress, App. Chem." XXV., 795.

disclose the fact that this is due to the particles of oxide of zinc having entangled a much greater quantity of air than either the whitelead or the barytes, and the material which seems so light in comparison with the two last-named pigments is not oxide of zinc but *oxide of zinc plus air*.

The relations between weight and volume in mixed paints are often confusing, particularly when these are expressed in terms of the prevailing English system. An extended acquaintance with the specific gravities of the pigments and mediums of which paint is composed goes a long way towards simplifying calculations relating to the conversion of dry pigments and medium into mixed paint.

If we take the specific gravity of water as unity (1.0), and knowing that a gallon of water at 60° F. weighs 10 lb., we know at once that a gallon of a pigment whose specific gravity is 4.02 will weigh 40.2 lb. It is evident further that one gallon or 40.2 lb. of this pigment mixed with one gallon of a medium the specific gravity of which is 9.02 will produce a mixture which will weigh $\frac{40.2 + 9.02}{2} = 24.61$ lb. per gallon and of which the specific gravity is 2.461.

The bearings of such points as the foregoing on manufacturing problems and practice will be made clearer in the section which deals with the volume of mixed paints (Chap. XIII).

The specific gravity of a pigment, moreover, determines to some extent the behaviour of that pigment when suspended in various liquid mediums, and in certain cases the determination of the specific gravity of a pigment is a simple way of determining its freedom from adulteration or admixture with other pigments.

There is some relation between the specific gravity of a pigment and the proportion of oil required to grind the pigment into a uniform stiff paste, the general law being that the weight of oil required is inversely proportional to the specific gravity of the pigment. This law, although true in the main, is not without exceptions and ceases to

apply when pigments of widely different natures are compared.

The following table gives the specific gravity of typical pigments as determined by the author :—

Red lead, commercial samples vary from	8.62 to 9.19
Orange lead, commercial samples vary from	7.91 to 8.54
Whitelead, highest figure for English stack made	6.60
Whitelead, chamber made and foreign corroded	5.48 to 6.48
Oxide of zinc, chemically pure	5.65
Oxide of zinc, direct process	5.50
Oxide of zinc, indirect process	5.00
Lithopone	4.26
Barytes, best	4.45
Barytes, second white	4.02
Blanc fixé	2.45
Paris white	2.60
Asbestine	2.76
Gypsum	2.51
Chrome yellow, normal lead chromate	5.80
Yellow ochre, good quality grinding ochre	2.35
Oxide of iron, chemically pure Fe_2O_3	5.12
Purple brown, commercial sample	4.23
Burnt Turkey umber, commercial sample	3.02
Light Indian red, commercial sample	3.36
Silica	2.65
Graphite	2.2 to 2.5
Carbon black, under	2.0
but varies from	1.75 upwards

It must of course be understood that owing to the inevitable fluctuations in the composition of commercial and natural products there is no such thing as a fixed specific

gravity for each pigment. It is advisable, therefore, for every paint manufacturer to determine the specific gravities of the pigments he uses in his own laboratory. These data, along with the oil-absorbing powers of the pigments (which will be treated of later), are of great and growing practical importance.

The weight of the English or Imperial gallon of any of the before-mentioned pigments free from air can be calculated by multiplying the specific gravity by 10.

The determination of the specific gravities of pigments may be carried out by the specific gravity bottle method by the application of the formula

$$S = \frac{W}{W^1}$$

in which W is the weight of pigment taken and W^1 is the loss of weight of the pigment when weighed in distilled water at 15.5°C . The value of W^1 is given by

$$W^1 = W - A + B$$

in which A is the weight of bottle + pigment + water required to fill up bottle with water at 15.5°C ., and B is the weight of bottle + water only.

This method though capable of yielding very accurate results proves cumbersome in works practice, and there is often considerable difficulty in freeing the pigment in the bottle from air. A very much simpler and more expeditious method, and one which yields in most cases sufficiently accurate results, may be employed.

Take a rather narrow 100 c.c. measuring cylinder graduated in tenths of a c.c. and fill it up to the 80 c.c. mark with white spirit.¹ Have 20 grams of the pigment weighed out ready. Pour the pigment into the graduated vessel agitating the latter with a circular motion in order to

¹ Any rectified petroleum or benzol derivative will do, but a product with a comparatively high volatility point (such as the white spirit used in Britain) is better than alcohol, which, owing to its volatility, is liable to introduce an error. On the other hand alcohol is better than white spirit for freeing the pigment from minute air bubbles.

disentangle air bubbles. Note the increase in volume of the contents of the cylinder. Divide the increase in volume into the weight of pigment taken, and the quotient will be the specific gravity of the pigment. The temperature should be kept constant otherwise an error will be introduced owing to the expansion of the liquid.

For example, 20 grams of a pigment were poured into 80 c.c. of white spirit. The new reading was 86.5 c.c., an increase of 6.5. The specific gravity of the pigment was therefore

$$\frac{20}{6.5} = 3.077.$$

In careful hands this method is accurate to 1 or 2 units in the second decimal place, and even greater accuracy may be secured by refinements of manipulation in the matter of measuring the increase of volume.

Paint-forming Properties.—Even after the colour, opacity, tinctorial power and specific gravity of a pigment have been determined and examined, and inferences as to the value of the pigments have been drawn therefrom, there remain to be considered several properties of the pigment, chiefly physical in their nature, which exert no little influence on the practical utility of the pigment as an ingredient of paint and to which, for want of a better name, the general term *paint-forming properties* may be applied. Crystalline structure, size of particles, and tendency to fall out of suspension in a liquid medium are among the properties which influence the suitability of a pigment for paint making. The ease with which the particles of a pigment can be reduced in size during grinding is another factor which may render a pigment suitable or the reverse for paint making, for the reason that the cost of reducing a given pigment to the requisite degree of fineness may put it out of court for a specific purpose. The tendency of certain pigments to settle out from the medium with which they are mixed, and the indifferent manner in which others work under the

painter's brush, are illustrations of defects arising out of poor paint-forming properties. The texture, fineness and crystal-line structure of the particles all influence to a greater or less extent the paint-forming qualities of a pigment, yet these qualities cannot with any degree of certainty be predicted from the previously ascertained chemical composition, or from the various physical properties already referred to. A safe rule to follow where practicable is to put every pigment which it is proposed to use in paint to a working test, noting the behaviour of the pigment during the grinding process, and allowing the paint so prepared to stand for some time afterwards in order to see whether the proper consistency is maintained.

A point which should always be borne in mind is that the medium in which the pigment will ultimately be suspended may modify or alter the properties of the pigment to a considerable extent. Hence a pigment might be condemned if associated with one medium, but might give excellent results in another. This point will be discussed further in Chapter XII, but as a well-known illustration the behaviour of whiting in an oil medium and a water medium respectively may be cited.

Linseed Oil.—With regard to linseed oil, which is by far the most widely used medium in paint grinding, and which also enters very largely into the composition of many mixed paints, there are many points beyond the determination of the purity of the oil which will repay attention, especially in cases where the manufactured goods are to be of specially fine quality and are to be used for special purposes. Thus different samples of linseed oil vary in their drying properties, and also in the durability of the film formed when drying has taken place. Variations such as these are likely in the future to be greater than ever on account of the varying origin of the seed from which the oil is expressed, and also from the circumstance that, in consequence of the enormous increase in the consumption

of the article, it is likely to find its way into the paint factory in an exceedingly new condition, and containing a considerable quantity of albuminous matter which cannot fail to exercise a distinctly prejudicial effect on the texture and wearing qualities of paint produced from it. One has only to look to the kindred industry of varnish making to appreciate to what an extent the quality of the oil makes or mars the manufactured product. The varnish maker having learned by experience is most careful not only with regard to the quality of the oil he buys, but also in seeing that it is suitably tanked and aged before he commences to use it.

Unhappily market conditions often render it difficult if not impossible to lay oil into stock with that regularity which strict adherence to technical principles demands, but nevertheless much can be done to mitigate the evil effects produced by new or cloudy oil if a proper system of storage tanks is arranged.

The presence of moisture in linseed oil is a particularly objectionable feature, especially when the oil is to be used in enamels or other preparations intended to dry with a lustrous surface. Testing of the oil for drying and thickening properties should always be carried out as soon as a parcel is received, in order that any abnormalities or peculiarities it may present may be known and allowed for during the manufacturing processes.

The same remarks apply with equal force to tung oil and other raw materials of like nature which are used by the modern paint maker.

PART II.

CHAPTER IV.

PLANT AND MACHINERY.

IN such an industry as paint making, in which mechanical operations on a large scale play an important part, the influence of the machinery employed affects in no slight degree both the quality and the cost of the manufactured product. For a long time the operations connected with paint making were regarded as being of a peculiarly mysterious and secret nature, and were jealously guarded by the privileged persons engaged in the trade. Hence was evolved that system of "trade secrets" and recipe-mongering from the trammels of which the industry is at last being freed. The light of applied chemical and physical science has illuminated the twilight which surrounded trade secrets and rule-of-thumb, and the time has come when the manufacture of paints can be conducted advantageously only on sound and clearly defined scientific principles.

There is little room for doubt that a great deal of the progress which has already been made in this direction is due to the assiduity and skill with which various engineers and engineering firms have improved and devised machinery to enable the paint manufacturer to face altered conditions, and to keep pace with the steadily increasing demand for his commodities. But there are natural limits to this process. A mechanical engineer cannot be expected to possess the specialized knowledge of a practical paint grinder, any more than the latter can hope to be familiar with all the intricacies of mechanical science. But the scientifically

trained and practical paint grinder can do this,—he can see in what respect a certain mill or portion of machinery fails to accomplish what is required of it, and he can express intelligently to the engineer what it is desirable to accomplish. The engineer can then on his part employ his special skill in providing means to accomplish the object in view.

The first desideratum in paint machinery is of course the capacity to turn out work in as high a state of perfection as possible; the second is to accomplish this in as economical a manner as may be. Very little reflection is needed to discover that the economy aimed at may refer to time, or to power consumed, or to wages of workmen or to a combination of all three elements. Perfection in results united with economy in working implies *efficiency*. Before a grinding mill or a mixer can be termed efficient in the true sense of the word, it must satisfy both these requirements. If we take the case of a piece of mixing machinery, the following are a few of the points on which the intending purchaser may be expected to satisfy himself: Will the mill mix quickly and thoroughly a variety of paints, or is it adapted for only one class? Is it equally suitable for paints containing a large proportion of oil and for exceptionally stiff paints? Can it be easily charged, discharged and cleaned out with a minimum of manual labour? If for use in connection with poisonous pigments, can it be rendered proof against leakage of dust? What power is required to drive it?

Similar pertinent inquiries may be made with regard to grinding mills. The prime cost of the mills, within limits, is of secondary importance. There is no doubt difficulty in resisting the temptation to save a few pounds on the price of a mill when a cheaper one is offered with the positive assurance that it is as good as its more highly priced rival. But one should always remember that a grinding or other paint mill is of the nature of a mechanical

tool—a labour-saving appliance—and that a little extra initial outlay is immaterial, provided the outlay procures that perfection of fitting and detail which more than anything else tends to ensure easy working, slow depreciation and low cost of production.

Labour-saving machinery relating to any one of the numerous processes involved in paint making ought to inspire the keenest interest on the part of the paint manufacturer, because the item of labour is often one of the heaviest cost charges in the manufacturing process. Furthermore, the greater the extent to which machinery takes the place of manual labour the less will the personal element enter into the result. This may not always be a good thing, but in many of the operations of paint making it tends to ensure regularity and uniformity.

Paint-mixing Machinery.—The ultimate object of the mixing process is to bring the pigment or pigments undergoing treatment into such intimate and uniform association with the fluid medium, whatever may be the nature of the latter, that the process of grinding is facilitated and results in a perfectly fine, uniform, and stable paste in the shortest possible time. A mixing process which results in a product of unequal composition, or containing lumps or masses of dry material embedded in the surrounding paste, cannot be considered satisfactory. Not faultless either is one whereby the desired results are arrived at only after an unduly prolonged mechanical operation. Again, certain forms of mixing plant prove themselves thoroughly efficient only in cases where large quantities of oil or other medium can be used. Since pigments vary widely as regards the proportion of oil necessary to produce a paint of the proper consistency, this of necessity means that such types of machinery as those just indicated are useful only for a limited range of materials.

With regard to the rival claims of the various leading types of mixing plant—edge-runners, positive geared pan-mills, vertical pug-mills and horizontal mixers—it is wise to

preserve a perfectly open and unbiassed judgment. Each one of these is better than the others for some particular purpose, and the experienced skill of the practical paint maker will be shown in the judicious selection of well-made mills of the construction best suited to his particular requirements.

Edge-runners.—The edge-runner mill consists of a suitably constructed runner or pair of runners rotating on edge within a circular pan. The single runner mill is no longer

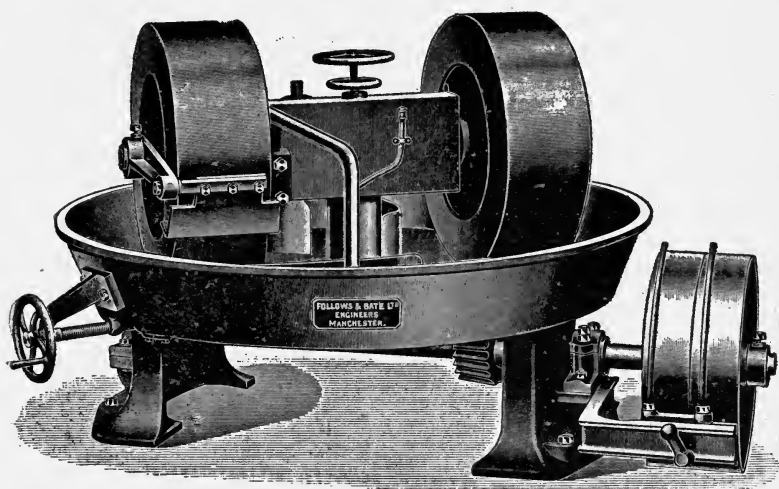


FIG. 2. —Iron edge-runner mill.

used in Britain, although in America there are a good many mills of this type. The two-runner mill is preferable, not only on account of its greater mechanical stability, but also because when driven at the same speed as the single runner mill double the effect is produced.

Figs. 2 and 3 indicate the construction of a favourite type of under driven edge-runner. The horizontal steel driving shaft is carried straight through from side to side and is supported at each end in adjustable gun metal bearings. It is essential that the faces of the runners and pan are turned dead true, as the slightest unevenness or inequality

on the surfaces in contact reduces the efficiency of the mill.

The diameter of the pan usually varies from 4' 6" to 5' 6" at the top, and from 4' to 5' at the bottom, and the depth

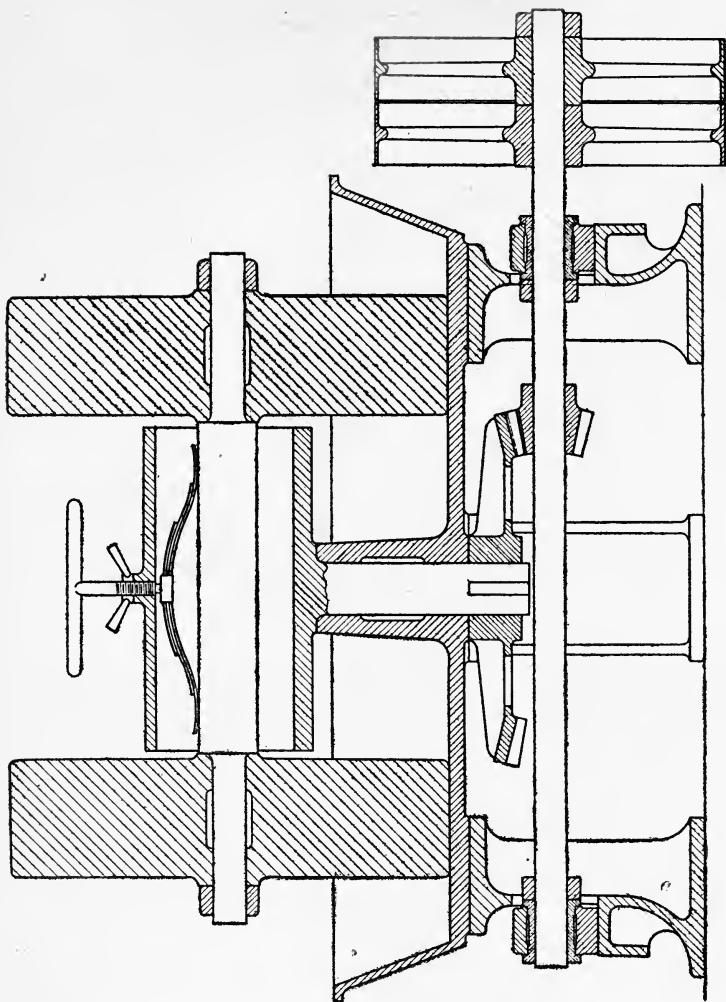


Fig. 3.—Section of iron edge-runner.

varies from 8" to 10". The runners are usually 30" in diameter and from 8" to 10" across the face. Their weight varies from 13 to 16 cwt. When the mixing operation is

completed the pan is emptied by turning the hand wheel shown on the left of Fig. 2.

These mills should not be driven at too high a speed, sixteen to twenty revolutions per minute will usually be found to be ample, this speed being in effect doubled owing to the presence of the two runners.

For certain purposes it is desirable to replace the iron bed and runners by granite, and the depth of the pan may

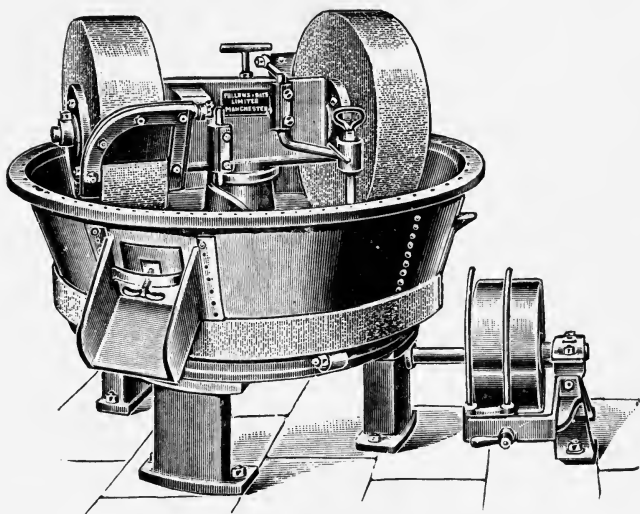


FIG. 4.—Granite edge-runner mill.

also have to be increased. A mill modified in these particulars is shown in Figs. 4 and 5.

The efficiency of the edge-runner type of mill as a mixer and also as a grinding agent depends upon its mode of action.

Consideration will show that the motion of the runners is not simply a rolling one, but that a "twist" takes place between the rolling edge of the runner and the pan, and much of the efficiency of this type of mill is due to this action, which is by no means dependent on the weight of the runner.

The edge-runner type of mill can be adapted for special

purposes by the addition of a water-cooling or steam-heating

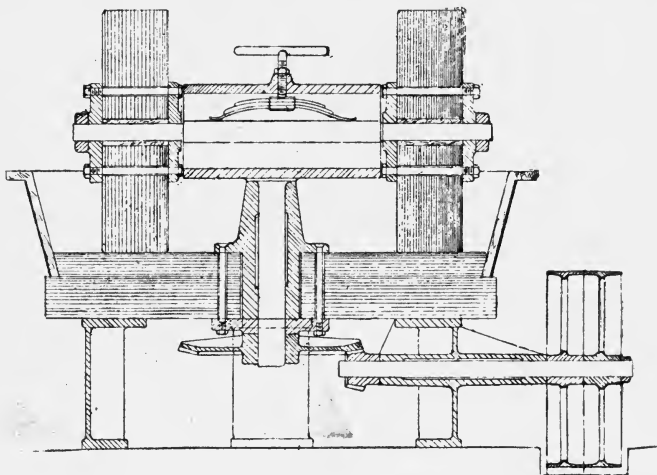


FIG. 5.—Section of granite edge-runner mill.

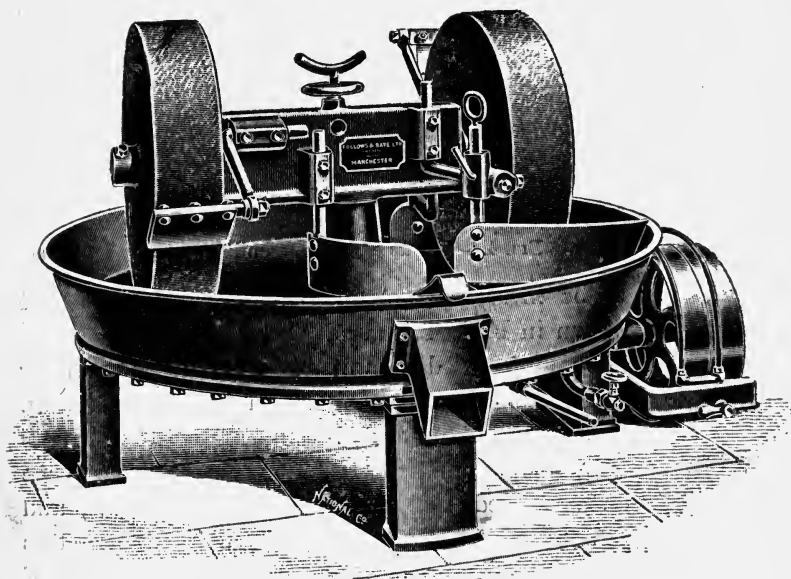


FIG. 6.—Iron edge-runner mill with water jacket.

arrangement. Fig. 6 shows a jacketed edge-runner of this kind. Hitherto this type of mill has been used principally

in the chemical industries and in the grinding of mixtures at low temperatures, as in the manufacture of explosives. It is quite possible, however, that these mills would prove useful in the mixing of certain types of water-paints, the ingredients of which must be kept warm to prevent solidification. In this case the mill would be adapted as a steam-jacketed mill.

A modification of the fixed pan type of edge-runner has come into favour owing to improvements in its construction. This is an edge-runner with revolving pan. In mixing and grinding dry pigments this mill is very efficient, and its adaptability for the treatment of paste-paint has resulted in the designing of improved types. One of these is shown in Fig. 7. It is particularly suitable for mixing pastes containing low percentages of oil or other medium, the efficiency of the mill depending on the maintenance of a more or less stiff consistency in the contents of the pan. These must be carried round by the pan as the latter revolves, otherwise the peculiar action on which the mixing and grinding depend does not take place. In the case of certain types of mixtures and paints, the revolving pan type of edge-runner has a good deal to recommend it and it requires a low power to drive it. The diameter of the pan varies from 3' to 4' at the bottom and the runners weigh from 5 to 13 cwt. each. The pan runs on a cast steel ball thrust bearing.

The chief mechanical details of the type of ball-thrust bearing used in the revolving pan edge-runner mill are shown in Fig. 8. It is a simple ball bearing placed under the toe of the vertical shaft, underneath the pan, and lightens the drive materially. The bearing proper is made up of a pair of hardened steel plates or washers between which is inserted a set of steel balls.

Positive-driven Edge-runners.—The fundamental defect in the old type of edge-runner mill is the tendency which the runners have to slip or skid on the oily and slippery surface of the pan. This tendency is of course

greater in certain circumstances than in others, but under the everyday conditions of paint-making the tendency is undoubtedly present, and has had the effect of limiting the use of the ordinary type of edge-runner mill in certain well-

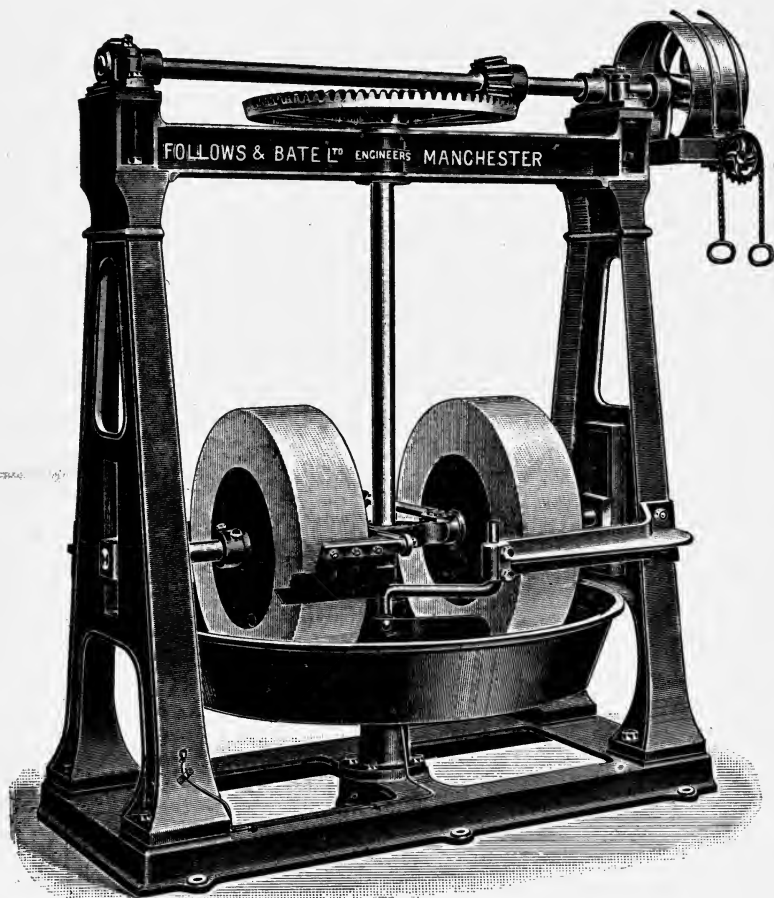


FIG. 7.—Iron edge-runner mill with revolving pan.

defined directions. An immense impetus has been given to the use of edge-runners for mixing paste-paints by the perfection of what is now usually known as the *positive-gear*ed edge-runner. In this type of machine the rotation of the

runner is not due to friction between its face and the surface

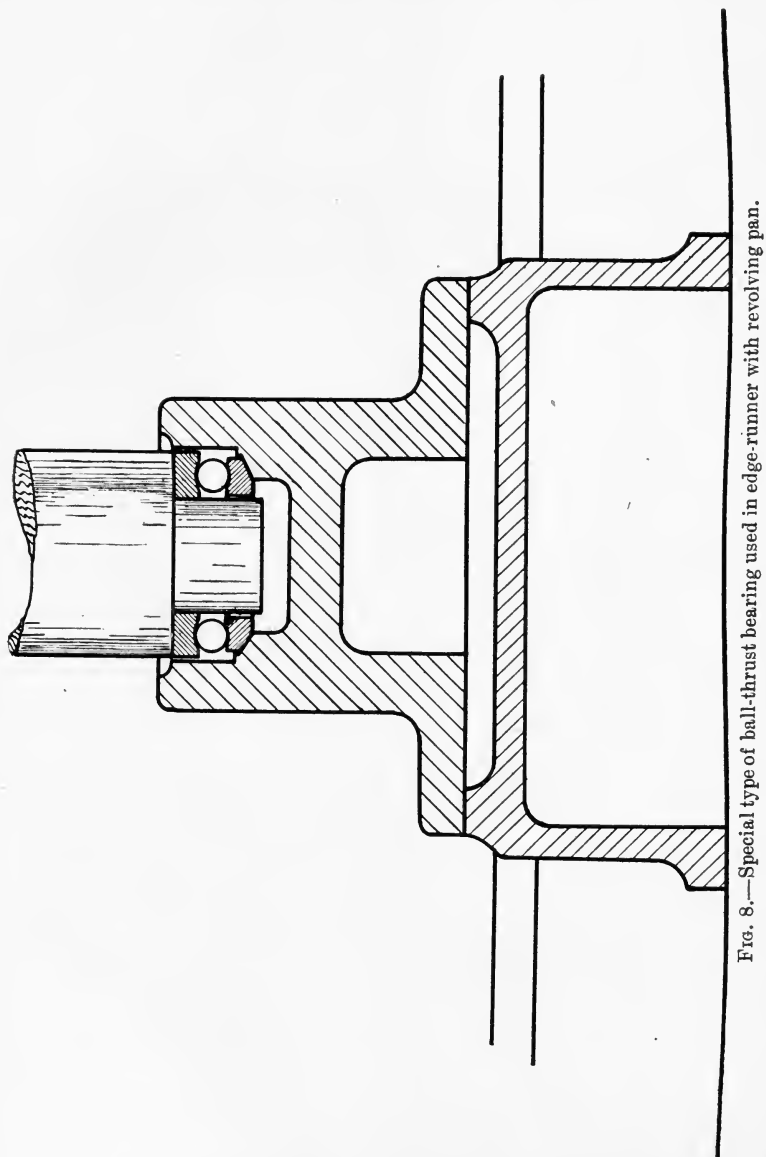


FIG. 8.—Special type of ball-thrust bearing used in edge-runner with revolving pan.

of the pan, in other words it does not simply roll round the

pan, but is geared directly or positively with the driving shaft. In addition to this the gear is a differential one, and the result is that while the runner is swept round the pan by the lateral arm on which it is mounted it revolves positively and differentially. There is therefore no slip or skid, and every particle of solid matter that finds its way between the runner and the bed must of necessity be crushed and

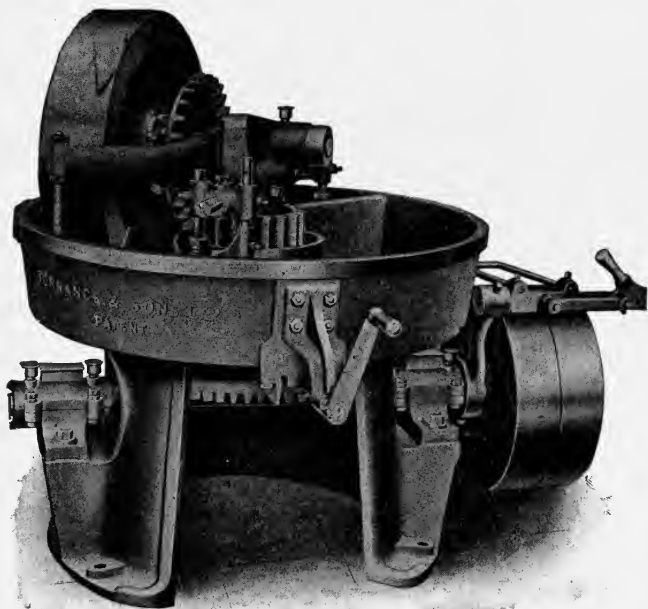


FIG. 9.—Positive-driven iron edge-runner with one runner.

mixed with the surrounding medium. This action is, of course, intensified by the twist of the runner as it is forced from a straight path into a circular one. In this type of mill the weight of the runner exerts a very definite and direct effect.

Much of the efficiency of a positive-gear edg-runner will depend on the fitting of the scrapers or doctors both on the runner and on the side of the pan. The aim should be to ensure that every portion of the charge comes successively under the runner.

Care and skill are required in charging this type of mill, as owing to the rigidity of the runner careless feeding in the early stages of mixing may pull the machine up or cause a breakdown. Figs. 9, 10 and 11 indicate types of positive-gear-ed edge-runners. The single-runner type is that most commonly used, and the pan which does not exceed 6' in diameter is perhaps the best. Extremely efficient mixing accompanied by considerable grinding effect is obtained from the

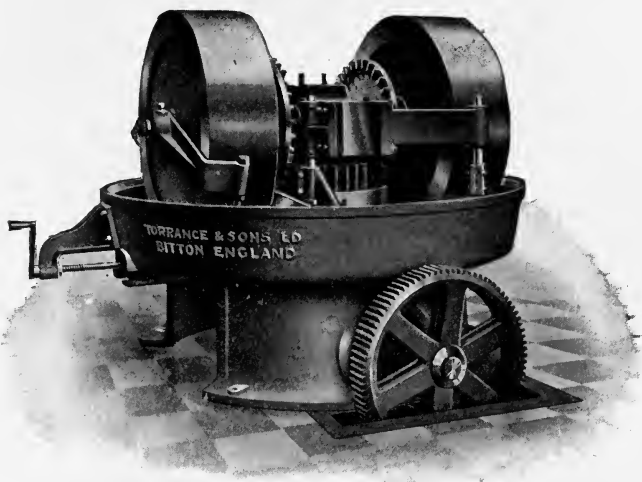


FIG. 10.—Positive-driven iron edge-runner with two runners.

large mills of this type fitted with two runners. For special purposes the runners and the bed of the pan may be of granite and the depth of the pan may be increased. A water-jacket arrangement may also be included as in Fig. 12.

It is inadvisable to drive these positive-driven mills too fast, 16 to 20 revolutions of the vertical spindle per minute according to the type of mill and the nature of the work are usually ample.

Vertical Pug-mills.—For many years this type of mixer held the field in the paint trade. The singularly unsatisfactory manner in which many of these pugs worked, their slowness and general inefficiency, caused them to go out of

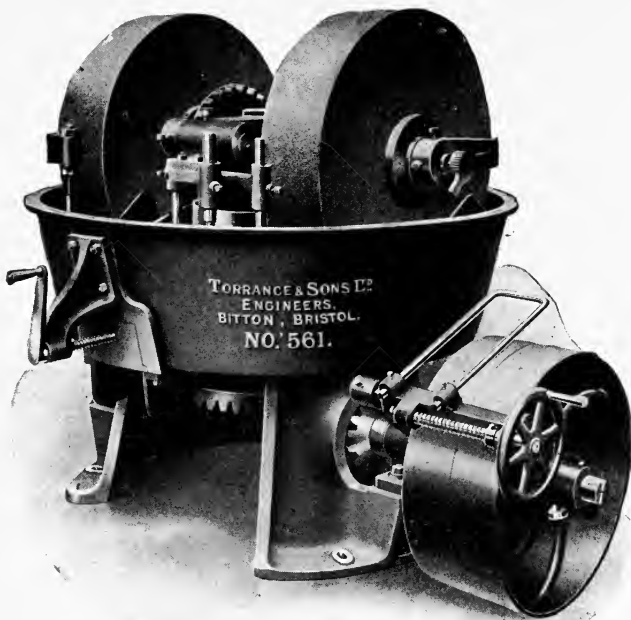


FIG. 11.—Positive-driven iron edge-runner with two runners and high sides.

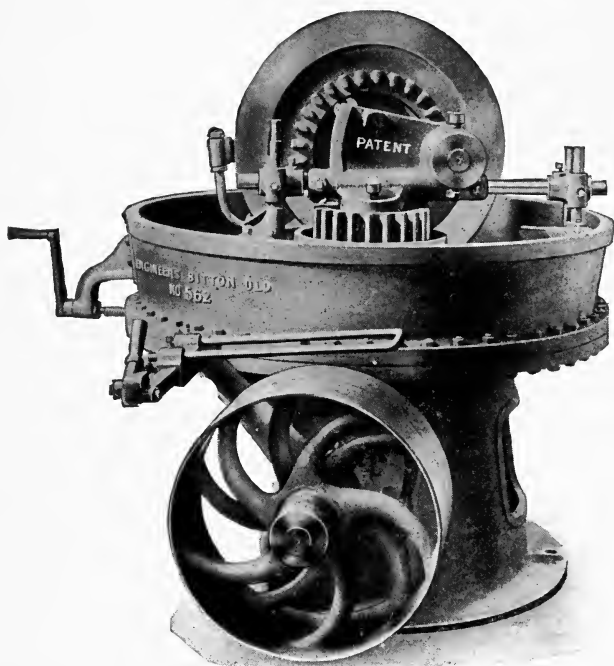


FIG. 12.—Positive-driven iron edge-runner mill, jacketed type.

favour, and although they are perhaps the simplest form of mixing plant known they were among the last of the types in general use to be taken in hand by competent engineers and brought up to date.

For many purposes the positive-gearred edge-runner is better than the vertical pug-mill, but nevertheless there are

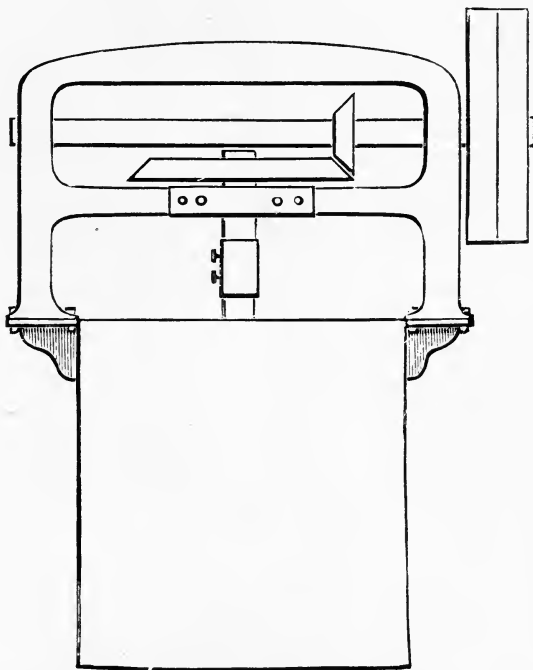


FIG. 13.—Skeleton diagram of a type of vertical pug-mill. The framework carrying gearing is bolted to brackets on side. Spindle is in two parts, and can be taken out of bearing by unbolting plate on transverse bar of frame.

certain directions in which the latter machine, improved as it has been during the last ten years, is pre-eminently suitable. In the first place its cost is not great ; secondly, its working parts are few in number and are simple, and there is hardly anything to get out of order ; thirdly, if fine powders are being dealt with, and if there is no necessity to combine mixing and grinding in one operation, quite good and

economical results can be obtained from a properly constructed mill of this type.

In Figs. 13 and 14 are shown in simple diagrammatic form standard types of vertical pug-mills. In Fig. 13 the gearing of the vertical spindle is supported by the sides of

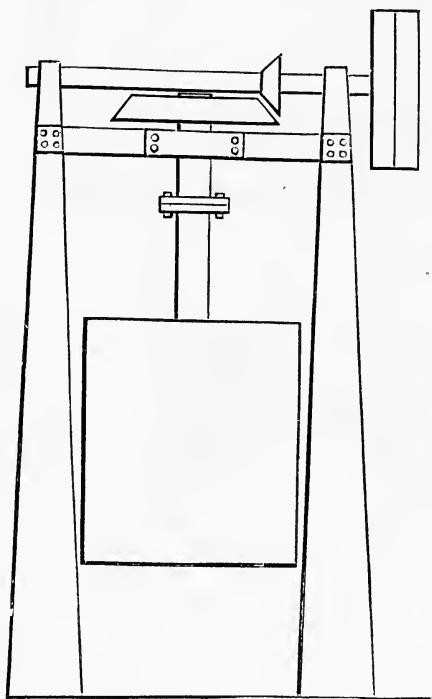


FIG. 14.—Skeleton diagram of vertical pug-mill in "A" frame. Spindle can be removed, as in Fig. 13.

the pug, while in Fig. 14 the gearing is supported by "A" frames.

Figs. 15 and 20 illustrate a modern form of vertical pug-mill with knives or beaters designed for dealing with fairly soft or oily mixtures. In the case of stiff mixtures such as whitelead a special type of knife is necessary. (See Figs. 16 and 17.)

It is now usual for makers of vertical pug-mills to take

special pains to secure that the internal face of the cylinder is perfectly smooth and free from hollows and slight inequalities, and this is a point of which the practical paint grinder

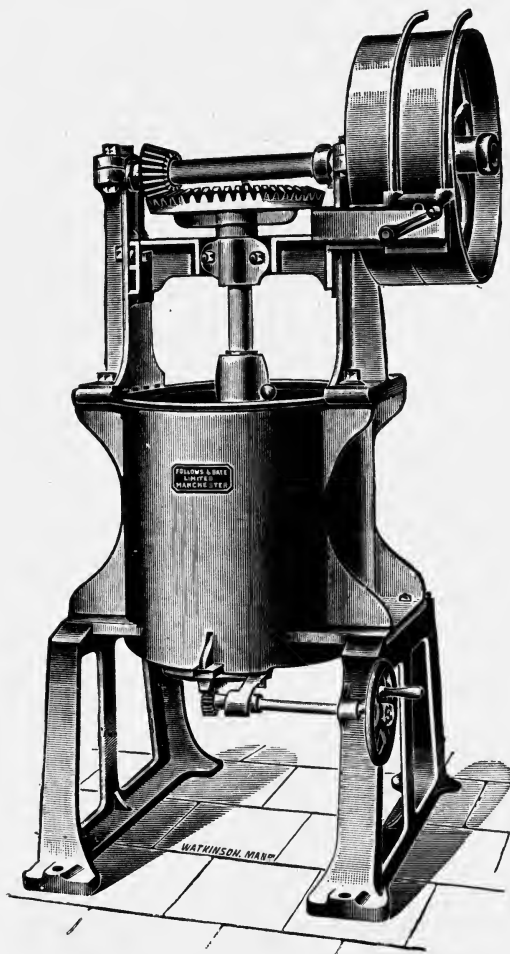


FIG. 15.—Vertical pug-mill.

will appreciate the importance. When a mixing mill is used for one colour only, the presence of a perceptible film of paint over such hollows and inequalities is a matter of

little consequence, but should it be necessary to follow one colour with another, then films of paint such as these described will probably cause trouble, for the colour contained in them, though small in quantity, is often sufficient to tinge a whole batch of paint and in all probability to spoil it. It is therefore important to have the surface of the pug itself, as well as the spindle and knives, as smooth and free from inequalities as possible. Indeed all such internal parts are now turned true on the lathe and then polished.

The structure and inclination of the knives and the manner in which they are set on the spindle is very important. The knives are set on two opposite sides of the spindle and should be bolted through, and should have a thickened piece or shoulder fitting into a slot on the side of the spindle. The direction of the slots on the diagram (Fig. 16) will indicate also how the knives should be placed, *i.e.* pointing downwards at an angle of about 30 degrees, and they should taper from the back or heel towards the cutting edge (Fig. 17). This point in the setting of the knives is one of the great secrets of efficient mixing, and in the older type of mills was quite neglected. To accomplish thorough mixing it is not sufficient for the knives to cut *through* the mass. But when the knives are set as described above, each knife cuts a circle with its lower edge, and at the same time exerts a pushing force with its upper surface, so that the particles stirred by its upper surface return after the knife has passed, not to their old position with relation to the particles below them, but to a new one, and this action going on continuously with all the knives accounts for the thorough mixture of oil and pigment which can be obtained with this form of plant when mixtures containing comparatively small proportions of oil are in question.

As regards the speed of the knives, provided the greatest care is taken in working, 30 revolutions per minute may be regarded as permissible, but this is the limit in ordinary



FIG. 16 —Bottom part of spindle, showing slots and bolt holes for knives.¹

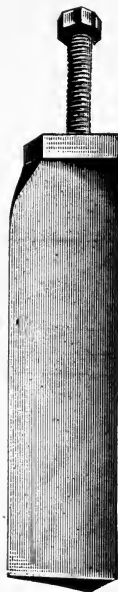


FIG. 17.—One of the knives disconnected from the spindle.

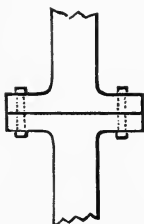


FIG. 18.—Flange coupling for spindle (bolted).²



FIG. 19.—Muff coupling for spindle with feather-key and two set screws.³

¹ The end bolts and bolt holes now usually of square section, a thread being cut on the outer end of the bolts. This prevents the knives from turning as they would be liable to do if the bolts are round and if they work loose on the spindle.

² Fig. 18. A disc between the two flanges should be shown.

³ Fig. 19. Another feather-key should be shown between the muff and the bottom half of spindle.

cases, and a speed of from 16 to 20 revolutions per minute is generally preferable.

Devices for keeping the mixing machinery cool during the operation of mixing have been designed, but are not in

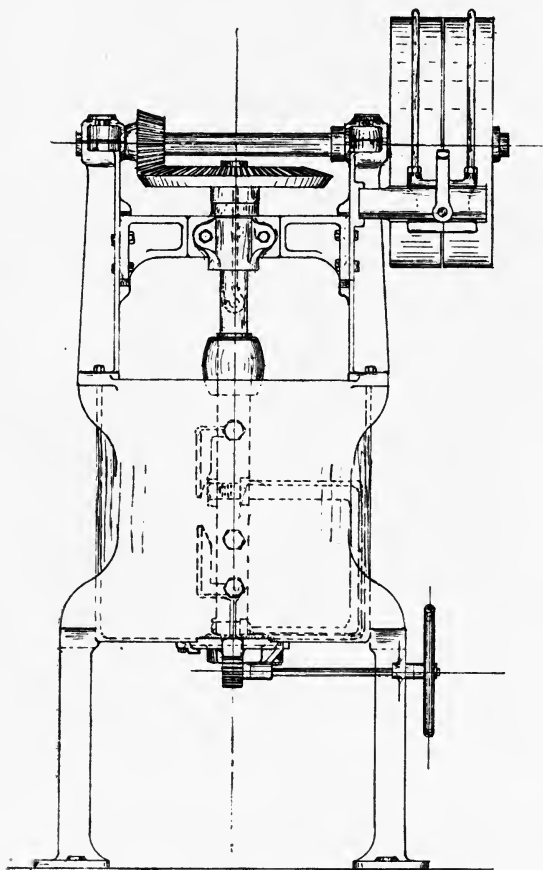


FIG. 20.—End elevation, vertical pug-mill, showing one form of knives.

general use. Water jackets have been tried, but have been discontinued in this country.

It is frequently a matter of practical importance to be able to remove the whole spindle quickly and without the intervention of skilled engineers. To accomplish this it is

recommended to have the vertical spindle in two parts, united either by a flange coupling (Fig. 18) or by a loose collar keyed on, and fitted with two set screws (Fig. 19). On the newest type of mill the knives or beaters can be removed quickly by loosening the sleeve on the central shaft (see Fig. 20).

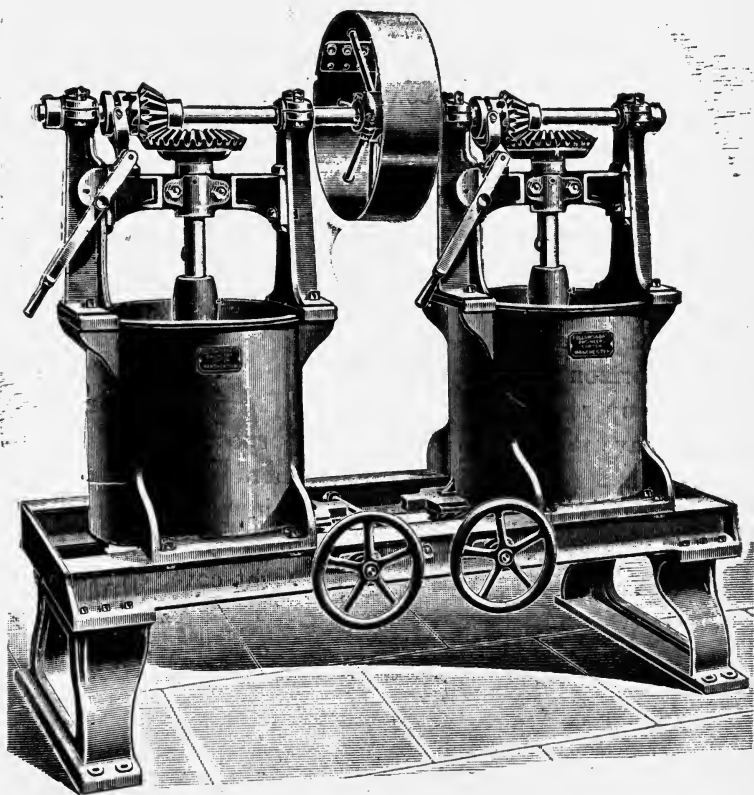


FIG. 21.—Vertical pug-mills in gang.

The door is usually placed on the bottom and is fitted with a machined water-tight slide which is opened by means of the hand wheel shown on Fig. 15.

Vertical pug-mixers are often fixed in pairs or in gangs. Fig. 21 illustrates a pair of these mixers driven by a single

pulley placed between the two, while by means of a simple clutch arrangement either or both of the mills may be thrown out of gear.

Fig. 22 shows yet another type of vertical mixer which is adapted for delivering direct on to a set of triple granite rollers. Each pan shown in the illustration is cast with a heavy flange ring round the top through which the machines are bolted down to the upper floor. The pans project through the ceiling of the grinding room and deliver on to the grinding mills. A combined mixing and grinding plant is shown on p. 78.

The capacity of modern vertical mixers varies as a rule from 30 to 100 gallons, 60 gallons being a useful capacity. In dimensions they vary from 24" x 24" to 27" x 27", the working depth and the diameter being usually the same. In Chapter V. some practical notes are given on the handling of mills of this class.

Horizontal Mixer.—Although mixers of this type have been superseded to a considerable extent by other types they have their value for certain purposes as, for example, the mixing of finely divided pigments with oil or other medium in order to produce a thin paste or thick fluid. They are also useful in cases where the medium is volatile (*e.g.* in turpentine colours) as a tight cover can readily be fixed on the top of the mixer.

A mixer of the simplest horizontal form is shown in Fig. 23. The lower portion is cast in a half circle. The slide door at the bottom is opened and shut by a screw with wheel attached. The spindle may pass through both ends of the pug, or may rest at one end in a bush fitted in a recess in the casting. The supports may consist of a framework resting on the ground, or of a pair of "A"-frames, the pug in this case discharging on to the rollers. The chief drawback to these mixers is the difficulty in cleaning them. When they are made so that the cover can be completely removed, and the spindle bearing the beaters or knives

quickly and easily taken out, this objection vanishes. It is

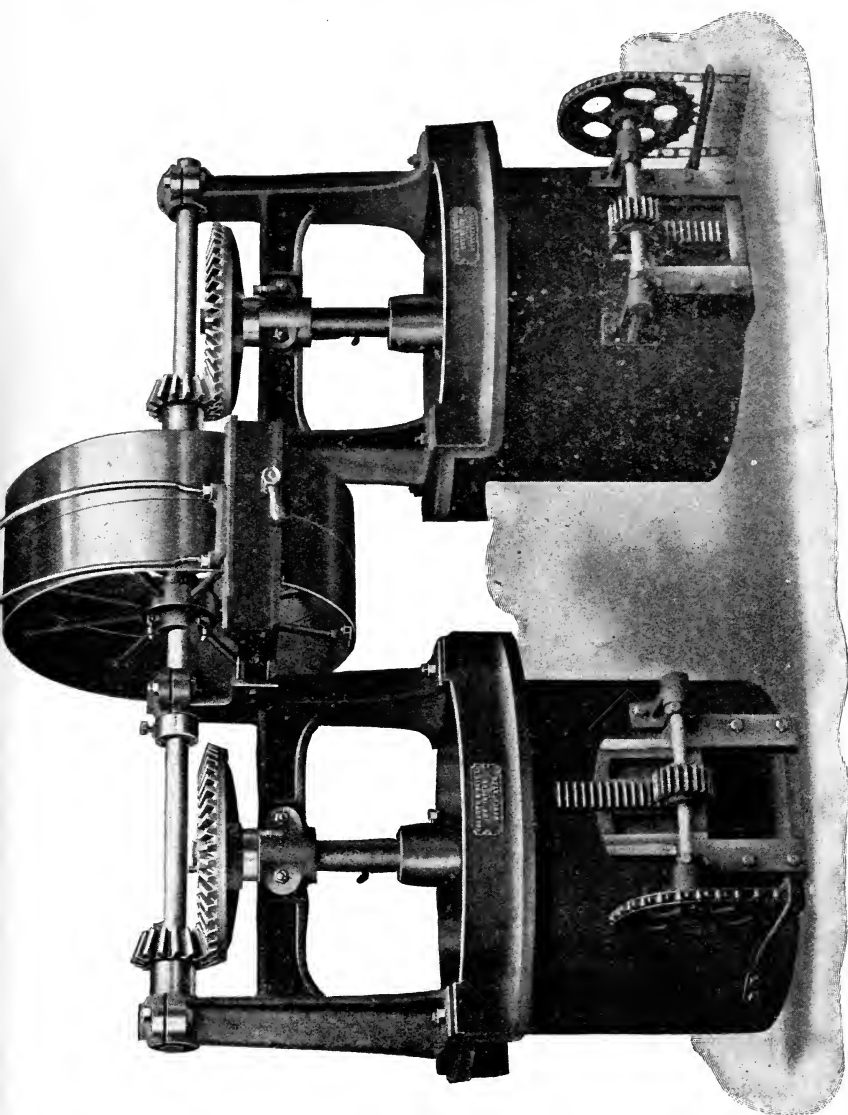


FIG. 22.—Pair of vertical pug-mills placed on floor above grinding mill.

not usual to make mixers of this type in large sizes, a capacity of from 3 to 5 cwt. being common, the dimensions

varying from 24" \times 24" to 30" \times 36". It is convenient to have two such mixers erected side by side over a set of rollers. A still further advantage is secured when the charge can be admitted by a shoot from the floor above.

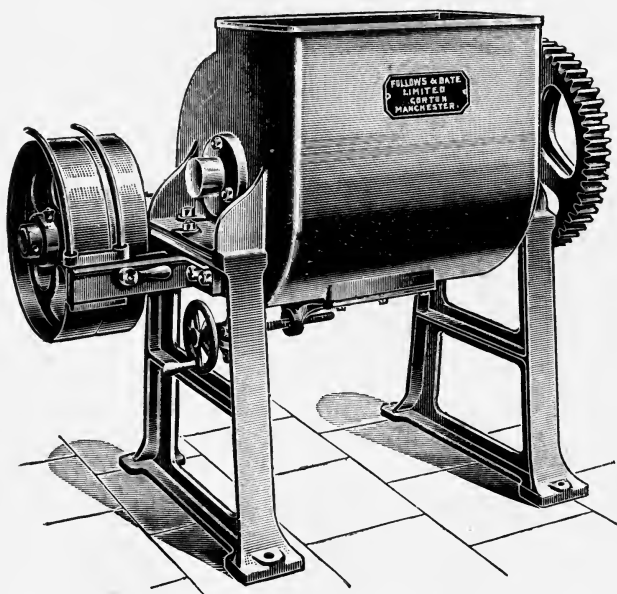


FIG. 23.—Horizontal mixer.

To secure quick and efficient mixing attention must be given to the speed, shape and position of the knives. The speed must be sufficiently great not merely to cause the knife to cut through the mass, but to keep it in some sort of agita-



FIG. 24.—Diagram showing curvature of one of the knives or beaters.

tion. From thirty-five to forty revolutions per minute will suffice to effect this. The knives should be of forged steel and of such a shape that every portion of the paint mass is brought under their influence. Probably no pattern is more efficient than that consisting of three laterally curved

blades fixed radially on the horizontal spindle. The spindle should be placed in such a position that the edges of the

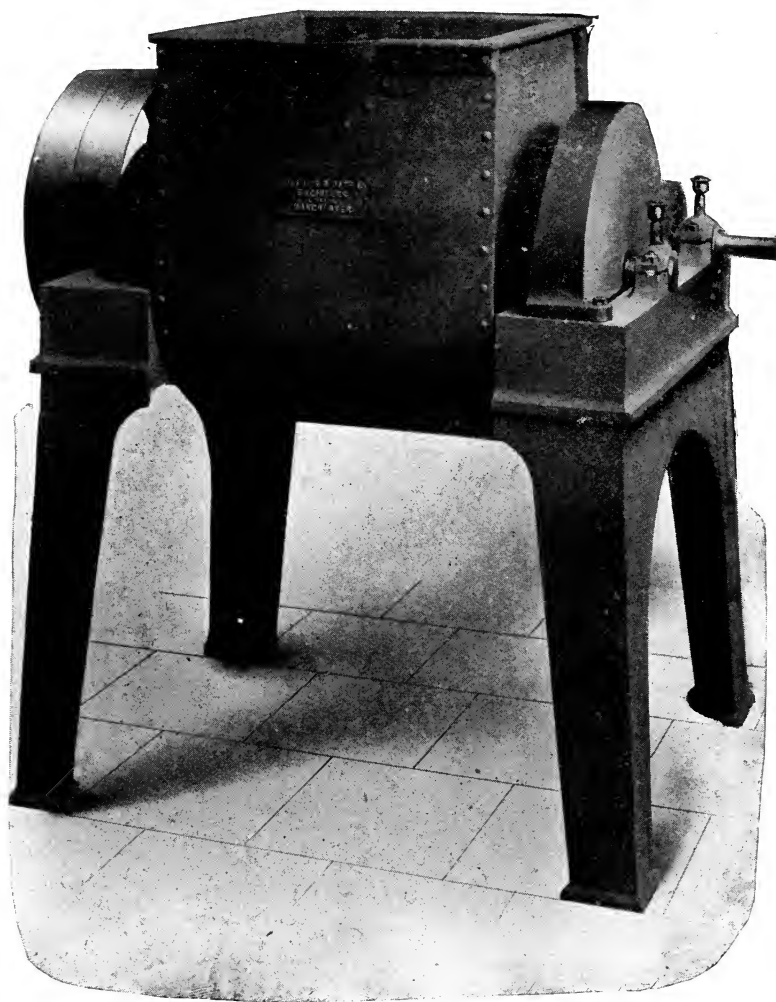


FIG. 25.—Horizontal mixer with beaters revolving in opposite directions.

blades just clear the bottom of the mixer. In this way no layer of unmixed material is possible, and, even when the

section of the knife represents a small proportion of the depth of the mixer, perfect mixing is obtained. When it is desired to clean out such a mixer quickly, as for example in changing from one colour to another, a simple and effectual method to adopt is to work up some whiting and

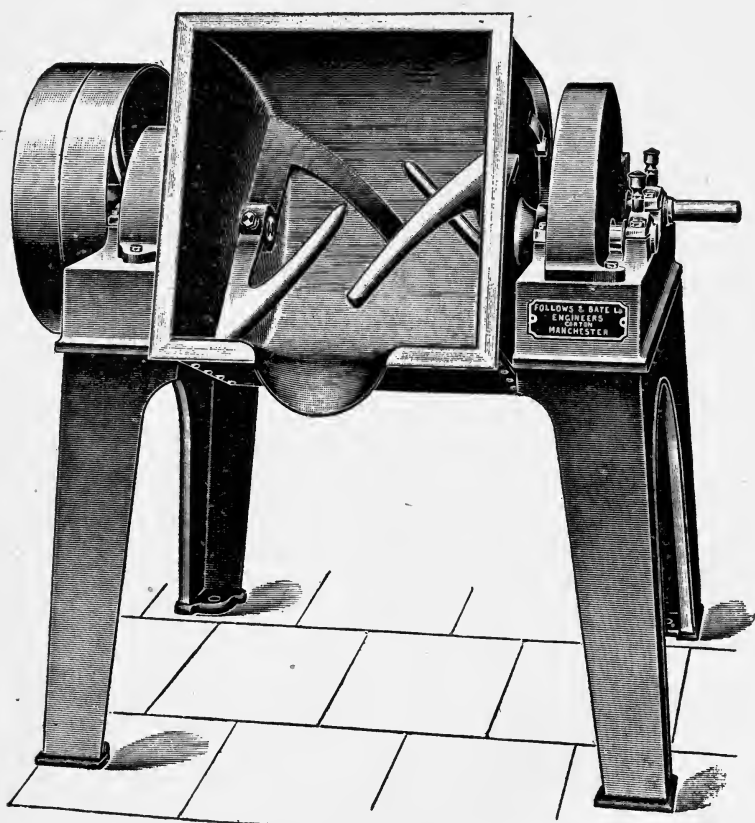


FIG. 26.—Horizontal mixer tilted for discharging or cleaning.

oil to the consistency of stiff putty. The mass will absorb all the colouring matter that will be likely to injure the tint of the succeeding batch.

In the type of horizontal mixer just referred to the

beaters or knives revolve in one direction. There is another and for certain purposes very efficient type in which the beaters are fixed on two separate spindles which revolve in opposite directions. A machine of this type is shown in Fig. 25 and the arrangement of the beaters and the manner in which the mixer can be tilted to discharge the contents is shown in Fig. 26.

The mixer illustrated in Figs. 25 and 26 is adapted for the mixing of materials whose specific gravity is not very high and in which there is a fairly large proportion of liquid medium. The container or hopper may be constructed of steel, copper or brass, and swings between two heavy standards and is locked by a stop catch which can be instantly released when the hopper is to be tilted. The gearing is covered in. The knives, which are made of toughened steel, rotate in opposite directions in such a manner as to prevent the contents of the hopper from gathering together into a ball or mass. This type of mixer is made in capacities varying from 10 gallons up to 60 gallons, and is specially adapted for the mixing of pigments and medium which do not require grinding, *e.g.* naphtha paints, certain kinds of anti-fouling paints and the like.

Paint-grinding Machinery.—The evolution of modern paint-grinding mills has probably taken place from two original and entirely distinct prototypes. The older of these is represented with but little essential change in the ordinary flat-stone mill, which is the lineal descendant of a form well known to the ancients. The simplest form of such grinding mechanism is provided by a muller worked by hand on a stone slab. The principle represented by the horizontal roller mill is, however, of more recent introduction. In this case friction due to differential speeds in the rollers has no doubt been introduced as an improvement on the original, which consisted simply of a pair of rollers of equal diameters rotating in opposite directions, so that their action was merely of a crushing nature. The simplest form of mech-

anism representing the latter type is 'a roller that rolls freely on a plane surface in the manner of the domestic rolling pin.

The modern edge-runner mill is founded on this type. The runner represents a section of the long roller, which may be considered as being held at one end while it is rolled forwards, thus causing the motion to become circular, while the plane surface on which the long roller in its free state would run is represented by the pan. Further analysis of the motion will show that here also we have differential movement between the face of the runner and the pan, because, to enable the action to be simply a rolling one, the roller would have to be a cone, and the runners of an edge-runner mill would have to be sections of such a cone.

The keynote of the efficiency of the modern triple-roller mill is the differential speed of the three rollers. A little consideration will show that if we were to increase the diameter of the rollers indefinitely their circumferences would approach nearer and nearer to straight lines. Hence we should ultimately obtain a grinding effect exactly comparable with that obtained in the flat-stone mill.

Inasmuch as the three-roller horizontal grinding mill is, on the whole, the mill which enjoys the greatest use, and as it will in all probability maintain its position on account of its all-round efficiency and economy, a few practical notes on the leading mechanical features of this style of mill may not be out of place. In regard to the general design of the mill, one pattern is practically universal, and to the uninitiated there would appear little room for divergence even in details. Yet it is precisely in these details that the suitability of the mill for its appointed work depends. Of these essential points brief notice will now be taken.

Frame.—Immense improvements have been made in the strength and rigidity of the frame. The height of the frame is kept as low as possible and every effort is made to eliminate vibration, which is fatal to good grinding. The greatest

variation in the frame consists in what we may term the *pitch* of the mill, which may be defined as the difference (P) in vertical height between the top and the bottom roller.

The high-pitch variety has two drawbacks—(1) there is a tendency to lateral vibration; (2) in setting the front or bottom roller for grinding the weight of the roller comes more into play, and tends to counteract the effect of the

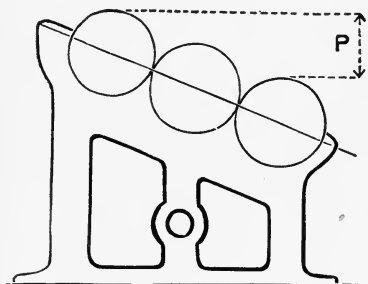


FIG. 27.—High-pitch mill.

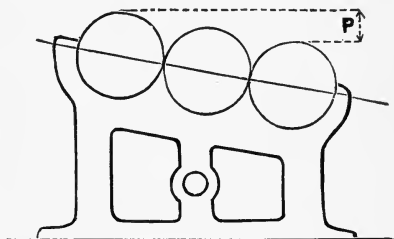


FIG. 28.—Low-pitch mill.

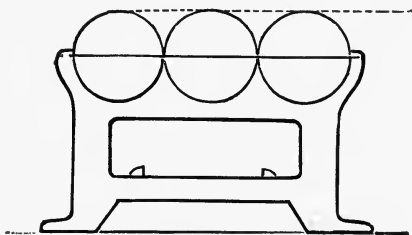


FIG. 29.—Mill with rollers in one plane. Provision is here made for counter-shaft to run in removable plummer-block.

setting screws. Where the three rollers are in one plane as in Fig. 29, the effect of gravitation in this connection vanishes.

Fixing.—Too much care cannot be bestowed on the fixing in position of a grinding mill. Absolute rigidity is essential, and the same remark applies to shafting, hangers, brackets, etc. It is essential that the rollers be set dead-level, otherwise it will be found that grinding takes place more on one side than on the other, and the roller will wear “sugar-

loaded". When the plant possesses considerable weight the bed should be prepared with great care, so that no sinking can take place afterwards. In the case of mills of heavy construction a bed of concrete should be prepared in which the holding down plates and bolts should be grouted.

Driving-gear.—All grinding mills of any size are now driven from a counter-shaft forming part of and situated under the mill. It should be remembered when laying down a mill that it may be necessary at some future time to renew the bearings of the counter-shaft, or to execute other repairs necessitating its temporary removal. Hence room should be left on one side at least to allow of this being done. Where space is limited the counter-shaft may run in bearings contained in ordinary pedestals with caps, bolted to the transverse bars of the frame, as indicated in Figs. 29 and 33. In cases where the power is communicated direct to one of the rollers, it is usually the middle roller that is so driven, but the system is an inferior one mechanically, and is now adopted only on small-sized mills.

Makers of grinding plant have their individual opinions as to the size, strength and pitch of the teeth requisite for the cog wheels. In general the tendency during recent years has been to make wheels having fewer teeth, but of coarser pitch. It is open to question whether this may not be overdone. With a finer pitch the motion is on the whole smoother and more continuous, but on the other hand the danger of teeth breaking through sudden jars is increased. All the gearing on well constructed paint plant is now machine cut. This is a great improvement on the old-fashioned moulded gear wheels, and results in much smoother running. A still later improvement is to have the gear running in an enclosed oil-bath.

As the rollers undergo wear and consequently reduction in diameter, the teeth of the wheels which impinge will obviously come into closer contact, and may ultimately "bottom". This should be carefully guarded against, as

it is a fruitful source of breakages and breakdowns. What is known as the "quadrant gear" attachment, which is fitted to Messrs. Torrance & Sons latest triple granite-roller mills, is a simple but ingenious device to remedy this evil.

Rollers.—When the rollers are of stone, granite of one kind or another is invariably used. The selection of stones suitable for conversion into grinding rollers demands both experience and judgment. Contrary to popular belief, it is not always the hardest stone that gives the best grinding surface. The stone must be itself capable of being scratched, so as to yield a surface that will "bite" the material which is being ground. A small and close-grained stone is usually selected, and it has to go through an elaborate process of cutting, boring and turning before it is ready to be fitted on a spindle and placed in a grinding mill. Fig. 30 indicates

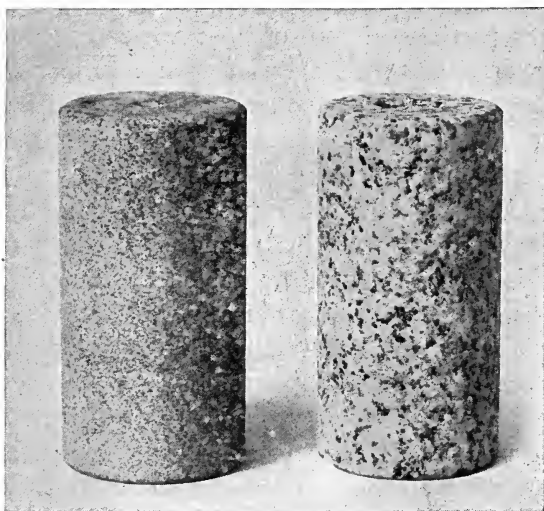


FIG. 30.—Types of granite used in rollers.

two types of granite used in grinding mills. The stone shown on the right is Scotch granite, which is suitable for ordinary grinding. The sample on the left is a much closer grained and harder granite, and is suitable for the grinding of fine pigments, oxide of zinc for enamels, and the like.

There are several methods of fixing the stone on to its spindle and flanges, and improper or careless fixing is one of the most frequent causes of stones breaking. As the breakage of a stone is one of the most expensive accidents that can occur to a mill, it is to the paint grinder's interest to take all possible precautions that such mishaps occur but rarely. If a spindle with its flanges is so fitted that it is possible for the spindle under any circumstances to revolve independently of the stone, the chances of disaster are increased. When one considers the conditions that obtain when a stone roller is running at a high speed, the necessity for extreme care is obvious. We have, in more or less close and rigid contact, three solid bodies—stone, iron, and either spelter metal or some fixing composition, one of these, the stone, being a highly crystalline substance. In all probability a considerable rise in temperature has taken place, so that the particles of each of the three components of the revolving mass are in a state of strain. Further, as the capacities of the three components to absorb and retain heat vary, the total mass is in a state of unequal strain. Add to this the fact that the roller is under severe pressure from without and is revolving at a speed of anything up to 100 or 120 revolutions per minute, and it is easily seen that the *external* conditions are favourable to fracture. If, therefore, there is any hidden flaw or any weakness due to faulty fitting, the result can hardly fail to be a breakage. These remarks are made with special reference to the front roller, which is the one that most frequently gives way. Each maker of paint machinery has his own particular way of fixing the stone on the spindle, and provided the usage to which the mill will be exposed is clearly explained to him he can be relied on to adopt a suitable method of fixing.

Speed of Rollers.—The grinding action of the triple roller mill is due essentially to the fact that each of the three rollers revolves at a different speed. Each one of the two pairs of rollers which are in contact does not simply

roll on the face of its neighbour, as would be the case if the diameter and number of revolutions per minute of each were the same, but by means of suitable gearing revolves at a speed which is different from that of either of the other rollers. It is this "differential speed" of the back and middle roller and of the middle and front roller respectively that causes that complex crushing, tearing, reducing and mixing action which we described by the term "grinding". The back roller always revolves at a slower rate than the middle roller, and the latter, in turn, is always slower than the front roller.

The question as to what is the best speed for the back roller and the best relative speeds for the middle and front rollers respectively as compared with the back roller is a much more complicated one than many people imagine. A number of factors have to be taken into account in answering this question. Some of these are the composition of the rollers, steel rollers being speeded differently from granite rollers; the diameter and weight of the rollers; the class of material which is to be handled; the output and degree of fineness required. In many of the best modern triple granite-roller mills the speed of the three rollers is in the ratio 1 : 2 throughout. That is to say the number of revolutions per minute of the middle roller is twice that of the back roller, and the front roller revolves twice as quickly as the middle roller. Hence if the revolutions per minute of the back roller is 25, the revolutions per minute of the middle roller will be 50, and of the front roller 100. Some authorities consider that 1 : 2 : 3 is a better ratio, while others again pin their faith to lower figures such as 1 : $1\frac{1}{2}$: $2\frac{1}{4}$. It is a wise plan when such questions arise to exchange views with a paint machinery expert, who, if he is provided with sufficient data, can usually tender valuable advice.

But there is a point in connection with the question of speed which is often overlooked. It is that a mere statement of the revolutions per minute of the roller does not

convey a true idea of the speed at which the faces of the rollers are travelling in relation to one another. A diagram will make this clear.

Suppose cc to represent the face of a roller 15" in diameter revolving at the rate of 25 revolutions per minute, then a point d on the face will traverse

$$\frac{15 \times 3.142 \times 25}{60} = 19.64'' \text{ per second.}$$

Now let us suppose $c'c'$ to represent the face of a roller 12" in diameter revolving at the same rate of 25 revolutions per

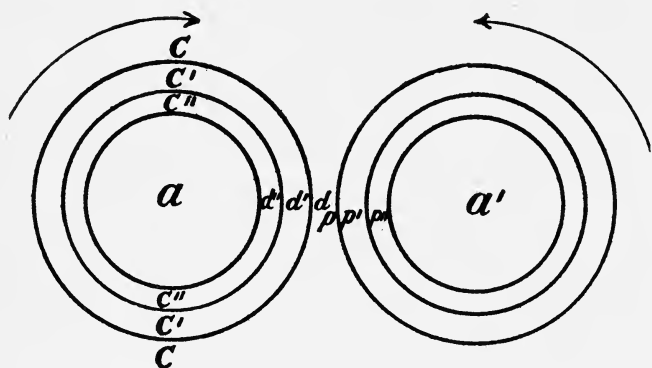


FIG. 31.—Diagram illustrating "surface velocity".

minute. It is apparent that a point d'' on its face will traverse only

$$\frac{12 \times 3.142 \times 25}{60} = 15.71'' \text{ per second.}$$

And again in the case of $c''c''$ the diameter of which we will suppose to be 10" the point d'' revolving at 25 revolutions per minute will traverse

$$\frac{10 \times 3.142 \times 25}{60} = 13.09'' \text{ per second.}$$

If we calculate in a similar manner the spaces traversed per second by points on the faces of the middle and front rollers respectively, and if we assume for the sake of convenience that the revolutions per minute of these are 50 and 100

respectively, we obtain the following figures, which represent inches per second:—

	15" diam.	12" diam.	10" diam.
Back roller at 25 r.p.m.	19.64	15.71	13.09
Middle „ at 50 „	39.28	31.42	26.18
Front „ at 100 „	78.56	62.84	52.36

From the above we see that the “surface velocity,” with reference to each other of two points, one on each of two rollers moving in opposite directions, will be the sum of the two corresponding figures given above, thus:—

	15" diam.	12" diam.	10" diam.
Surface velocity of back/middle rollers	58.92	47.13	39.27
Surface velocity of middle/front rollers	117.84	94.26	78.54

The importance of all this from the practical point of view is that the surface velocity determines the length of time during which the weight of the roller acts on the mixture of pigment and medium which is being ground. It is evident that this period is greater the smaller the diameter of the rollers, the revolutions per minute being assumed to be kept constant. From this follows the important practical rule: *In the case of heavy rollers of large diameter care should be taken not to drive them too fast.*

As this conception of “surface velocity” becomes familiar to paint-grinders, they will find it useful in solving problems which arise as to the best speed at which to work under various conditions.

If it becomes necessary at any time to “speed” a roller so as to produce a surface velocity of a given value, the required revolutions per minute of the roller can be calculated from the formula:—

$$\text{revolutions per minute} = \frac{19.1 \times v}{d}$$

in which v is the surface velocity aimed at
and d is the diameter of the roller.

Thus if it is desired to speed a back roller of 10" diameter so as to produce the same surface velocity as that of a 15" roller running at 25 revolutions per minute the calculation will be :—

$$\text{required revolutions per minute} = \frac{19.1 \times 15 \times 3.142 \times 25}{60 \times 10} = 37.5.$$

It is convenient, and it is now customary, to have but two sizes of toothed wheels in the train of wheels that enable the different speeds to be communicated to the rollers of a grinding mill. If the wheels are arranged as in the

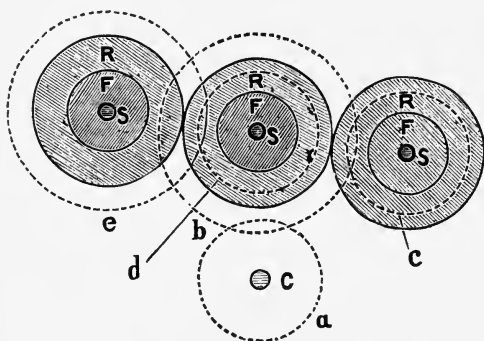


FIG. 32.—Diagram of usual spur-gearing of triple roller-granite mill. R, roller ; F, flange ; S, spindle ; C, counter-shaft. *a* (19 teeth) gears into *b* (32 teeth), which gears into *c* (19 teeth) ; *d* (19 teeth), on same spindle as *b*, gears into *e* (32 teeth). *a*, *b*, *c*, *d*, and *e* may be all at same side, or *a*, *b*, and *c* may be at one side and *d* and *e* at the other.

accompanying diagram (Fig. 32), it is obvious that the speed of the counter-shaft must also be the speed of the front roller.

As a calculation of speed sometimes offers unnecessary difficulty to those who are not in the habit of dealing frequently with such mechanical details, the rules bearing on this subject may perhaps be usefully included here. In general terms the speed is inversely proportional to the number of teeth. Or, expressing the same fact in other terms: Let *S* = speed of driving wheel, *S'* = speed of driven wheel, *D* = size (either diameter or number of teeth) of driving wheel, *D'* = size of driven wheel. Then—

The speed of driving wheel (*S*): the speed of driven

wheel (S') :: the size of driven wheel (D') : the size of driving wheel (D),

$$i.e. \quad \frac{S}{S'} = \frac{D'}{D}$$

$$\text{whence } S = \frac{D'S'}{D} \quad . \quad . \quad . \quad (1)$$

$$S' = \frac{DS}{D'} \quad . \quad . \quad . \quad (2)$$

$$D' = \frac{SD}{S'} \quad . \quad . \quad . \quad (3)$$

$$D = \frac{S'D'}{S} \quad . \quad . \quad . \quad (4)$$

As an example, let us suppose that it is desired to calculate the speeds of the front, middle, and back rollers of a triple granite-roller mill from the following data:—

Speed of main shaft, 64 revolutions per minute.

Diameter of pulley on shaft, 45".

Diameter of pulley on counter-shaft of mill, 27".

Toothed wheels, arranged as in Fig. 26, small wheel, 19 teeth ; large wheel, 32 teeth. Then—

$$\frac{64 \times 45 \times 19 \times 32}{27 \times 32 \times 19} = S' = 107 \text{ (nearly)—Speed of front roller.}$$

$$\frac{64 \times 45 \times 19}{27 \times 32} = S' = 63 \text{ (nearly)—Speed of middle roller.}$$

$$\frac{64 \times 45 \times 19 \times 19}{27 \times 32 \times 32} = S' = 37 \text{ (nearly)—Speed of back roller.}$$

Or to take another case, supposing it becomes necessary to replace the 45" pulley with a 40" one, what change would have to be made in the size of the pulley on the counter-shaft of the mill in order to retain the same speed on the rollers?

Using equation No. 3, and knowing that in the train of wheels under consideration the speed of the counter-shaft is also the speed of the front roller, we have—

$$\frac{64 \times 40}{107} = D' = 24'' \text{ (nearly)—size of pulley required.}$$

Setting Rollers for Grinding.—An undue amount of mystery appears to be associated by some with the everyday operation of setting a mill for grinding. It is undoubtedly a part of the operative paint grinder's duty which the master or his deputy ought to be able to superintend with some degree of practical knowledge. There may be and no doubt are exceptions, but frequently the paint grinder conducts the operation by rule-of-thumb, which means even in the case of an intelligent man that very considerable experience is necessary before he can be relied upon. It is advisable when a new mill, or a mill that has lain idle for some time, is being started to open all the rollers by slacking the setting screws. A mill that has been left tightly screwed up suffers a severe jar when started in that condition. There is also the danger of pieces of wood, nails, etc., having become lodged between the rollers of a mill that has been off duty. Numerous cases have occurred in which accidents to the rollers might have been avoided by opening them before re-starting.

It must not be forgotten that it is the pressure of the back roller against the middle roller which regulates the feed. They should be capable of being screwed so closely together that the minimum quantity of material can, if desired, pass between them. Some mills, satisfactory in other respects, fail through allowing too much material to pass between the feed rollers. Imperfect grinding is the result. The springs between the back and middle rollers should be thoroughly efficient, so that, in the event of any solid body passing through, the rollers may open and permit it to pass without damage.

In beginning to grind a particular paint, the best workmen start with the feed rollers as tight as possible and the grinding rollers rather open. The back roller is then gradually opened, and the front roller gradually closed, till the correct adjustment for the work in hand is obtained. It is obvious that the more open it is possible to keep the rollers,

consistently with good workmanship, the better, as both the output will be increased and the wear and tear lessened.

Before starting a set of rollers to work for the first time, or after they have been re-dressed or faced, it is well to test them. This is done in three ways—(1) By the straight-edge; (2) by the calipers; (3) by the water test. By applying the straight-edge longitudinally along each roller

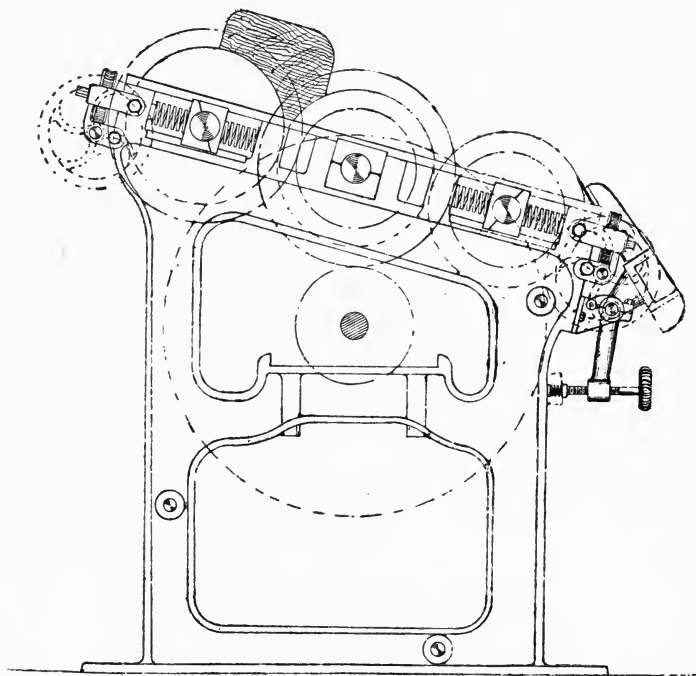


FIG. 33.—End elevation of three-roller granite-grinding mill, fitted with patent parallel roller adjustment.

in succession it is possible to discover whether the face is turned true. If it is so, the straight-edge will touch at every point. A spirit-level placed on the straight-edge will indicate whether the stone is set level. It is necessary, however, to use the calipers also, in order to take the diameter of the stone at three points, namely, at the two ends, and at the middle, because it is evident that a stone

might be turned or dressed so as to present a perfectly plane edge and still taper slightly towards one end, and this might not be discoverable by the straight-edge, on account of packing being introduced below one of the bearings. Should a paint factory not possess the appliances for turning and re-dressing rollers, it is well, before sending them away for this to be done, to caliper them, and to note the depth of the deepest groove or hole which has to be removed from their face. By calipering them again on their return the owner can judge of the manner in which the dressing has been conducted. Finally, when the mill is set up and ready for work, the water test is applied. All three rollers are screwed tightly up as in actual grinding. About three inches from each end of both pairs of rollers is inserted a large plug of putty, which is kneaded down so as to make a temporary hopper, with a tight joint between the stones. Water is then poured into the two hoppers so prepared. If the stones are true the water will remain for some time before it gradually leaks away. Nothing shows up hidden faults in the dressing or facing of the stones so quickly as this, but all three tests should be made before the work is definitely passed or rejected. Occasionally, in connection with a thorough cleaning of bearings and other working parts, it is a useful plan to apply these tests, as it is proved beyond dispute to be the poorest economy to keep machinery, and especially heavy machinery, running in a semi-worn or faulty state.

The Care of Rollers.—Wear and tear in grinding rollers is to be expected; at the same time pains should be taken to keep this within limits. It frequently happens that less damage is done by use than by abuse, and to avoid the latter the manufacturer has ever to be on the alert. Overheating of the stones is a cause of undue wearing. Granite, as is well known, contains numerous crystals of quartz embedded in a matrix of felspar. When a roller becomes unduly hot through too prolonged grinding of a material

offering considerable resistance and requiring little oil, the crystals of quartz on the surface become loosened and fall out, producing the effect known as "pitting". This action is greatly intensified if any acid is present. Thus in grinding whitelead containing traces of acetate of lead the destructive action on the rollers is very great. Excessive pressure on the stones is another frequent cause of undue wearing. An indifferent workman almost invariably attempts to make up for want of skill in adjusting the rollers by screwing them up as tight as they can be set. Only constant supervision by a competent overseer will prevent this abuse. The effect of the scraper on the life of the front roller is not inconsiderable, particularly if the scraper is made of hard steel. Too much pressure here also is to be deprecated. A roller that has undergone some wear will be more or less hollowed towards the centre, and may exhibit a number of grooves running round it. Such an appearance calls for immediate attention, as fine grinding is impossible under such conditions.

Grooving of the rollers is reduced, and often prevented altogether, by causing the centre roller to have a lateral motion, and most of the up-to-date mills are fitted with this adjustment. The old type of lateral movement consisted of a cam and pawle which is illustrated in Fig. 34.

This motion was exceedingly unsatisfactory owing to undue wearing of the finger with a corresponding decrease in the lateral throw. The stones also wore laterally along definite lines owing to the fixed position of the throw. Among the mechanical improvements which Messrs. Torrance & Sons have effected in paint machinery must be numbered their "ever-varying lateral gear" (Fig. 35), which consists of machine cut steel differential gear totally enclosed and working in an oil bath. It gives an ever-varying position of the roller for the lateral thrust. Hence not only is a real increase made in the grinding efficiency of the roller, but the life of the latter is prolonged and wear and tear reduced.

“Sugar-loafing,” or tapering, is a species of wearing which should never be allowed to take place. It may occur from a mill being off the level, or from continued faulty

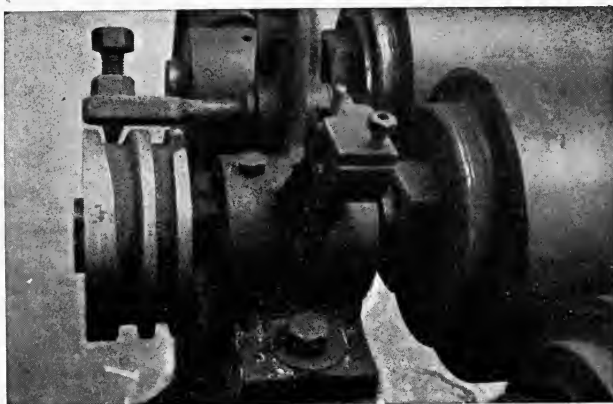


FIG. 34.—Arrangement for lateral movement on middle roller by means of cam and pawl.

adjustment of the rollers, and is usually associated with the scraper wearing obliquely.

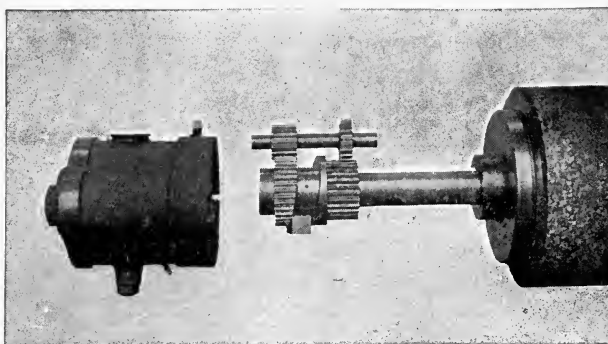


FIG. 35.—Torrance's ever-varying lateral gear.

Messrs. Follows & Bate, by whose courtesy the author has been enabled to include among the illustrations reproductions of drawings of some of their newest and most approved machinery, have perfected a little appliance which

mitigates the effect of irregular wear and tapering of the rollers, which so often involve costly repairs. To enable successful results to follow from the adoption of this appliance, however, the importance of having the mill set dead true, on a solid and immovable foundation, must not be overlooked.

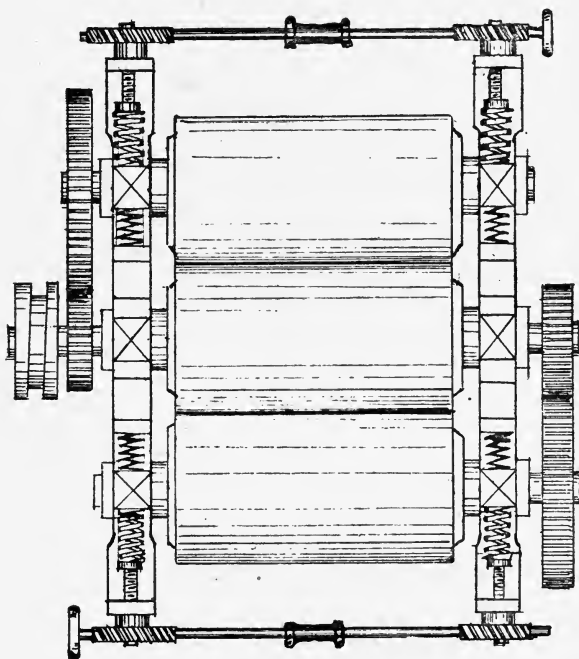


FIG. 36.—Follows and Bate's parallel adjustment (plan).

By this method, as shown in the Plan, Fig. 36, it will be seen that the adjusting screws are fitted with worm wheels, which are held in position by brackets secured to the mill-frame, which also carries the worms that operate the worm wheels. The two worms (shown in elevation, Fig. 37) on the front and back of the machine are coupled together by one shaft, and are operated by side hand wheels, as shown. One revolution of the hand wheels moves either roller in an absolutely parallel line—forward or backward—

opposite the middle roller, thus securing the even pressure and wear of the rollers from end to end, and effectually preventing them from being worn taper. When the machine has been adjusted, an arrangement has been introduced by

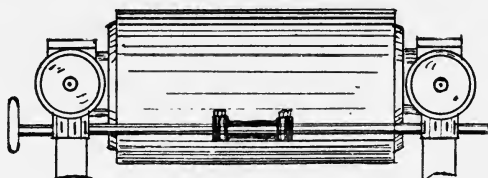


FIG. 37.—Follows and Bate's parallel adjustment (elevation).

means of which the adjusting wheels can be locked to prevent their being tampered with, thus ensuring the even quality of the product of the mill.

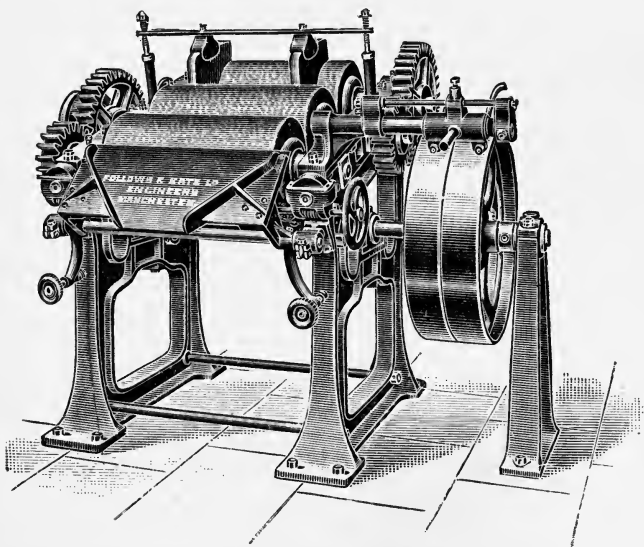


FIG. 38.—Three-roller grinding mill fitted with parallel adjustment and locking caps on adjusting screws.

It will be observed that the adjustment is applicable both to the front and back rollers. Fig. 38 represents a mill fitted with the arrangement, the worm wheels being capped over.

The Scraper or Knife.—At first sight there does not appear much room for divergence from a fixed pattern in this part of a roller mill. The practical man knows well how important a part the scraper plays; care in its selection and fitting is therefore well spent. The most usual fault with scrapers is that they are too thin and flexible. As the screws by which the scraper is adjusted to the circumference of the roller act only on the two ends, it is evident that any elasticity in the metal will have the effect of causing the contact to be less close at the centre. The metal should therefore be stout enough to render the scraper quite rigid. Opinions differ as to the most suitable temper of the metal for a scraper. Soft steel will certainly

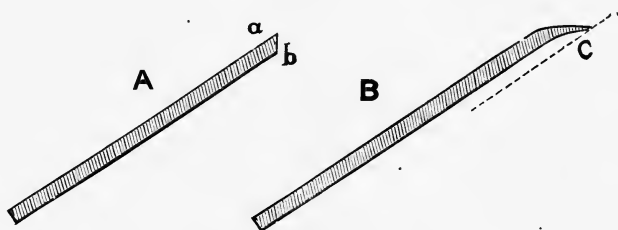


FIG. 39.—Sectional diagram of scrapers. A, with a bevelled edge; B, with sharpened edge turned over.

wear out sooner than a harder tempered metal, but if the mill is likely to be in the hands of any but careful and experienced workmen a rather soft scraper is perhaps an advantage, as it will have less effect on the roller. On the other hand, when a mill is well regulated, a hard steel scraper is rather an advantage, as it wears more evenly and requires less frequent attention.

A and B in Fig. 39 represent sections of scrapers as supplied ready to be fitted on a mill, but differing in the pattern of the upper edge. *a b* represents the usual form in which the edge is bevelled of. In practice it is very seldom that the surface *a b* fits exactly to the surface of the stone, and some time must elapse before the metal has worn into close contact. In B the edge is brought to a sharp

point c in the fire, and it is evident, since the point extends beyond the line of the under side of B, that at whatever angle B is placed the knife-edge c will still press against the stone, and being very thin will in a very short time fit

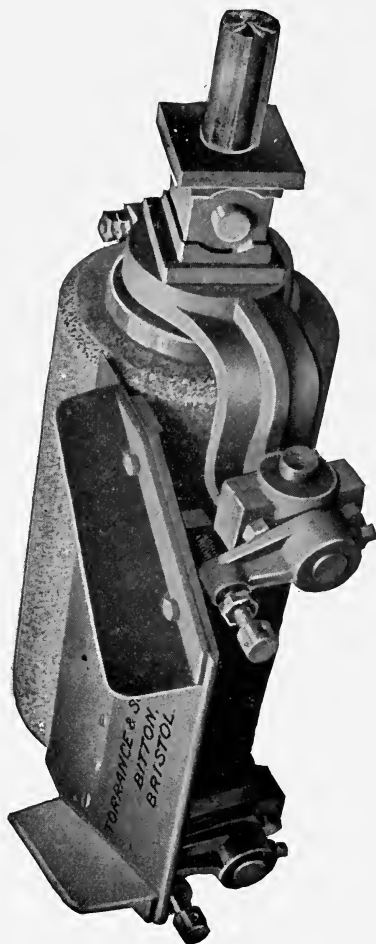


FIG. 40.—“Doctor” of Torrance triple granite-roller mill.

the roller with perfect exactness. A well-tempered scraper of the latter pattern has been known to last for eighteen months on a mill grinding whitelead continuously.

The fitting of most of the knives or “doctors” attached

to the triple granite-roller mills of twenty years ago left much to be desired. In the old types the scraper was attached to the frame of the mill, and consequently if for any reason the front roller got out of truth with the frame one of two things happened, either the knife on the scraper wore obliquely or it pressed unevenly on the roller. This defect has been overcome by attaching the "doctor" or scraper to the axis of the front roller. This ensures that whatever position the front roller may assume with reference to the mill-frame the edge of the knife is always in correct alignment with the surface of the roller. In this way close contact is always ensured, and wear and tear both of the roller and of the knife is reduced to a minimum.

Fig. 40 illustrates the front roller of a "Torrance" triple granite-roller mill detached from the frame and fitted with a "doctor" of the type described above. The arms carrying the "doctor" have a split boss through which passes a bolt, and by the unscrewing of a nut the angle of delivery can be instantly altered (see Fig. 41). The "doctor" is kept in contact with the roller by a simple screw and crank arrangement, and can be readily loosened and thrown back for cleaning. (Fig. 42.)

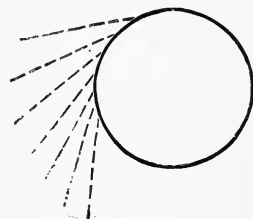


Fig. 41.—Diagram showing angles at which "doctor" can be fixed.

Types of Triple-roller Mills.—On p. 70 (Fig. 38) a typical triple granite-roller mill by Follows & Bate is illustrated. This type is in general use and is a sound serviceable machine. The dimensions of the rollers are usually either 24" \times 12" or 30" \times 15". The driving end of the counter-shaft is supported by a plummer block in a pedestal bracket. The rollers have a differential speed of approximately 1 : 2 : 4 from back to front, the actual revolutions per minute of the front roller in the 30 \times 15 size being about 100. The rollers are fitted with the parallel adjustment described on p. 69 and there is a lateral mo-

tion on the centre roller. The gearing is machine cut throughout.

A precisely similar type of mill can be obtained with the

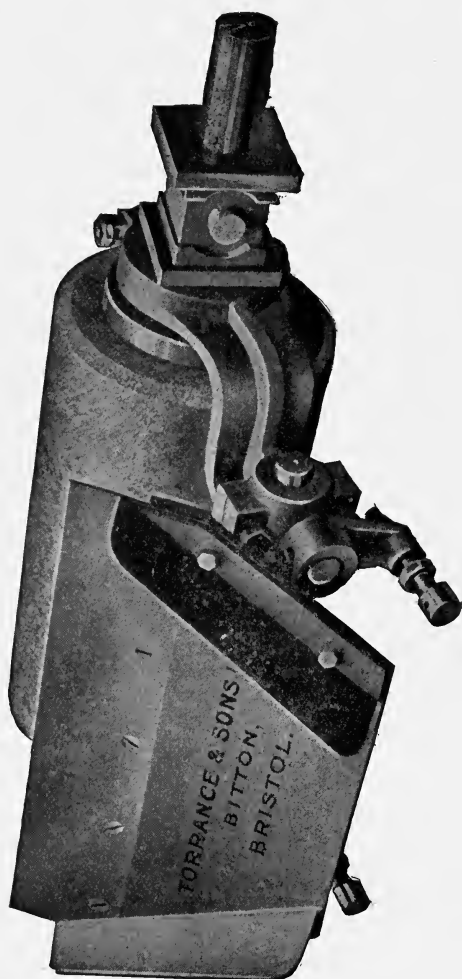


FIG. 42.—“Doctor” detached for cleaning.

rollers made of chilled iron mounted on mild steel spindles. Mills of the latter type are specially adapted for the grinding of printing inks and oily and viscous mixtures in which the pigment is already in an extremely fine state of division

and in connection with which the question of a large output per hour or per day does not arise. The mill illustrated (Fig. 43) has chambered rollers fitted with suitable inlets and outlets at ends of each spindle which permit the mill to be used either water-cooled, steam-heated or plain.

Fig. 44 shows an electrically driven water-cooled mill. In this particular mill the rollers are 30" long \times 12" dia-

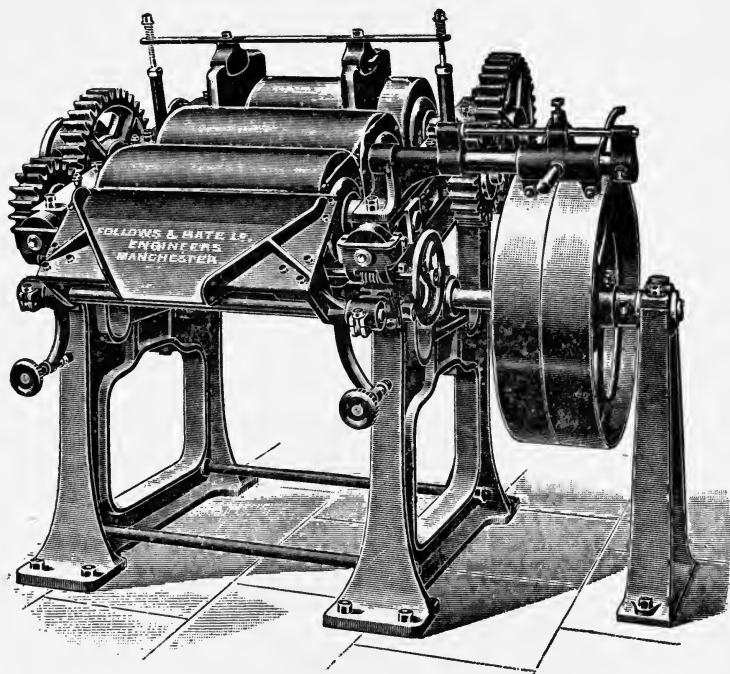


FIG. 43.—Chilled-iron triple-roller mill.

meter, the gearing is machine cut and the rollers are of close-grained chilled cast-iron, highly polished on the grinding surface and chambered inside. Each roller end is fitted with a specially designed stuffing box attachment, one end being used for the admission and the other for the discharge of steam or water. When the mill is arranged for both water cooling and steam heating a double set of pipes and valves are provided outside the mill. Mills of this type are em-

ployed in the grinding of special inks used in the preparation of carbon copying papers.

For the grinding of printing inks the front roller may have a speed of about 65 r.p.m. if the mill is to be used plain, that is without water cooling. For a water-cooled mill a speed of 90 to 100 r.p.m. on the front roller is usually quite safe. The speed of the middle and back rollers is reduced in the usual ratios.

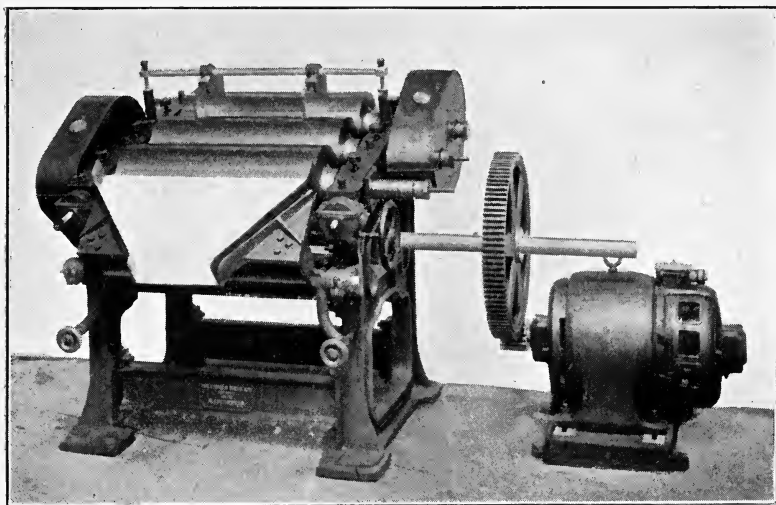


FIG. 44.—Chilled-iron triple-roller mill, steam-heated or water-cooled. (The right-hand end bearing of the shaft is removed for photographing.)

Chilled iron mills of the type described above are made in the following sizes: 24" \times 12", 26" \times 12", 26" \times 14", 30" \times 12", 30" \times 14" and 30" \times 15".

A small size (rollers 13 $\frac{1}{4}$ " \times 3 $\frac{3}{4}$ ") in a chilled iron mill is shown in Fig. 45. It is useful for small quantities of fine colours and for samples.

Fig. 46 represents a combination plant consisting of two vertical pug-mills of the type described on p. 48 elevated over a 30" \times 15" triple granite-roller mill of the type indicated in Fig. 38.

A mill of suitable size and of this type will turn out a large quantity (five to eight tons) of stiff paint of the lower qualities often sold for export.

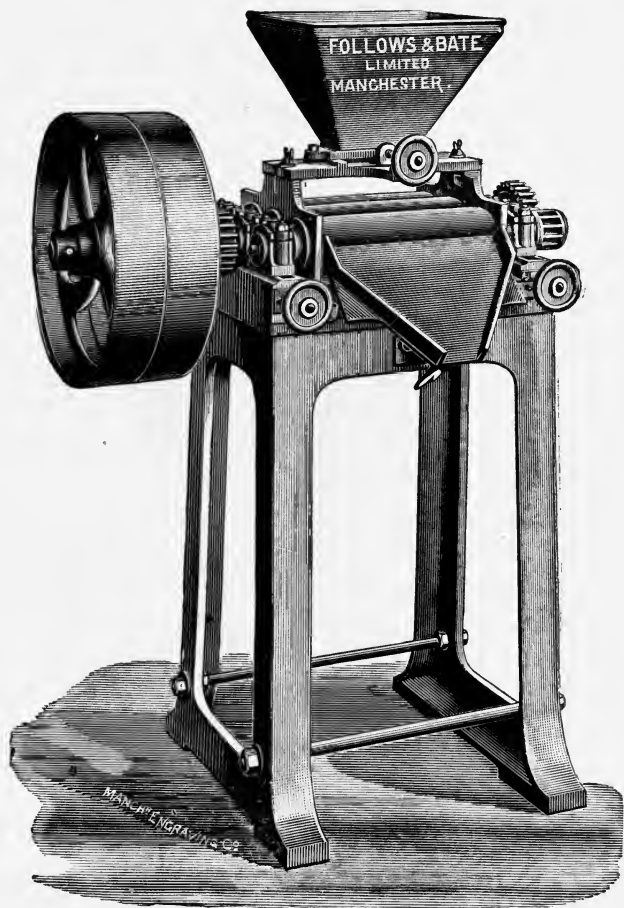


FIG. 45.—Small sized chilled-iron triple-roller mill.

In Fig. 47 is shown one of Torrance & Sons latest types of triple granite-roller mills. Note the low frame and the rollers set in a horizontal plane. The mill is fitted with the scraper shown in Figs. 40 and 42. There is a lateral movement on the middle roller (see Fig. 34). The

gearing is of their "patent quadrant" type and is totally enclosed and runs in an oil bath, which ensures extraordinary smoothness and absence of vibration in the mill, accompanied

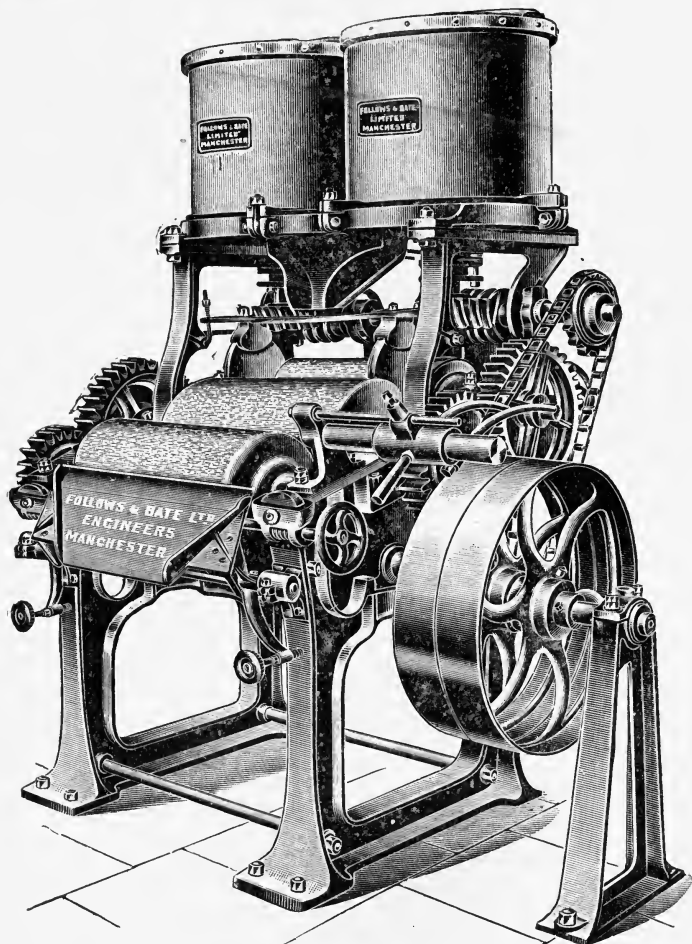


FIG. 46.—Combined mixing and grinding plant consisting of pair of vertical mixers and triple granite-roller grinding mill.

by a saving in the power required to drive the mill. The front roller of a 30" \times 15" mill of this type should not run at more than 100 revolutions per minute, and as a rule,

especially if perfection of grinding is aimed at, 90 revolutions per minute is ample. The "quadrant gear" (see Fig. 48) referred to above deserves a word in passing. Every one

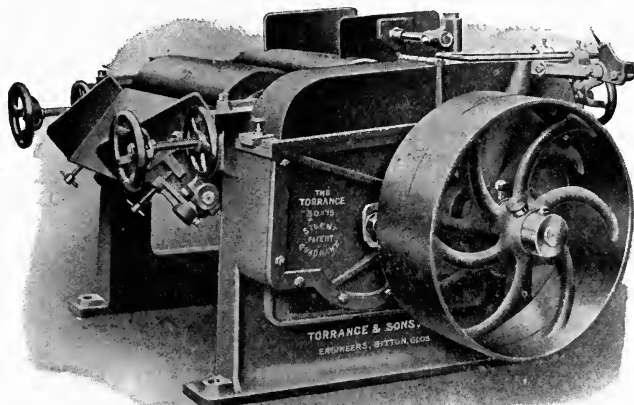


FIG. 47.—Triple granite-roller mill with patent quadrant gear.

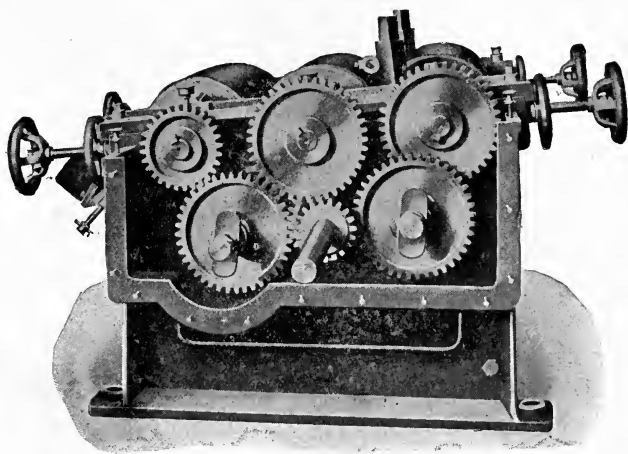


FIG. 48.—Torrance patent quadrant gear.

familiar with the roller mills of twenty years ago remembers the trouble and annoyance which were caused by the teeth of the pinions and spur wheels engaging too deeply after the

stones had become reduced in diameter. Jarring of the whole mill, excessive noise and broken teeth were at that time the order of the day, and laborious "tipping" and filing of the teeth had to be undertaken constantly in order to prevent the teeth from bottoming. In this new system of gearing the driving pinions are carried by two quadrants (shown in Fig. 49) which, while maintaining the proper depth of gear between themselves and the driving wheel, admit of a varying adjustment of gear with the driven wheel fixed on the roller spindle. In this way the necessity to fit new

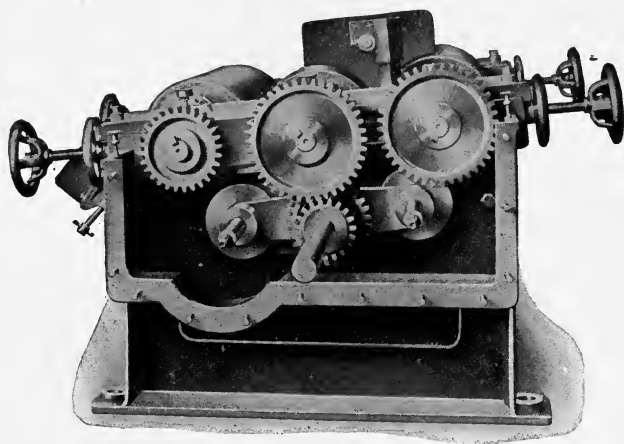


FIG. 49.—Part of gearing removed to show quadrants.

wheels or to alter the teeth of the old wheels is done away with, and moreover the original differential speeds of the rollers are retained throughout the whole life of the machine.

This gear is of great practical utility inasmuch as it enables alterations to be made in the ratio of the gears between either the feed and middle rollers or between the delivery and centre rollers. In order to increase the ratio between the feed and middle rollers the wheel on the roller is replaced by a larger one; to decrease the ratio a smaller wheel is substituted. In order to increase the ratio between

the delivery and middle rollers a *smaller* wheel is substituted for the one on the roller, and a larger one is substituted if it is desired to decrease the ratio. In this way variations in ratio can be secured should the special conditions of the case demand differential speeds varying from the normal, as is sometimes the case when abnormal materials are being treated.

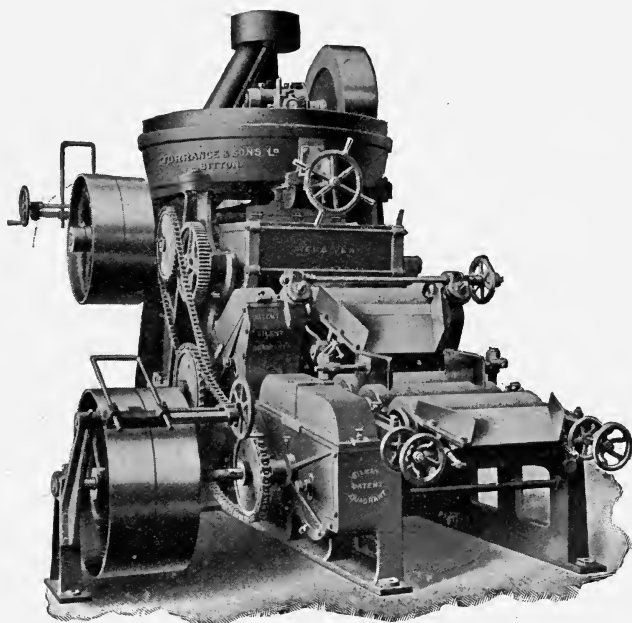


FIG. 50.—Combined positive driven edge-runner and two sets of triple granite-roller mills in tandem.

A “combination” mixing and grinding plant is shown in Fig. 50. On the top, and so arranged as to be capable of being fed from the floor above, is a positive-gear single roller edge-runner of the type shown in Fig. 9. As each charge of paste-paint is mixed it is discharged into the receiver placed above the rollers. Thence the material to be ground is fed on to the first set of rollers which are arranged in the particular case with the front roller at the top. From the apron of the first roller the ground paint falls on to the

second set of rollers which are practically identical with those shown in Fig. 47. The plant illustrated is fitted with belt drive, but in many of the newest plants an electrical drive is substituted, the motor (20 to 25 h.p.) being fixed between the back standards of the machine. Thus the whole plant becomes self-contained.

The advantages which accrue from the use of electricity as the motive power for paint plant are being recognised widely, and most modern works which can command a supply of electric power are employing electric motors in

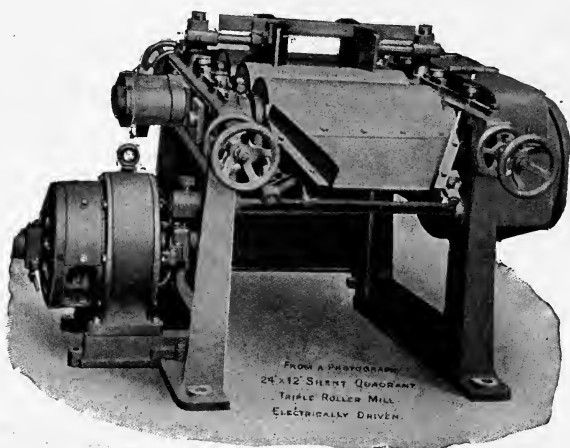


FIG. 51.—Direct electric drive on a triple granite-roller mill.

place of steam and gas engines. By the use of electric motors of suitable power attached to each machine or group of machines waste of power is prevented, as while the mill is idle the motor can be stopped. The very considerable loss due to power consumed in overcoming friction in long stretches of shafting is also avoided. Fig. 51 shows a 24" \times 12" triple granite-roller mill driven by a small motor which engages directly with the driving spindle. The subject of electric power is dealt with further in Chapter XVI.

In Fig. 52 is shown an up-to-date installation consisting of a positive-driven Torrance edge-runner mill (which is fed from the floor above and is totally enclosed in order to pre-

vent dust escaping) and two sets in tandem of "silent quadrants" 30" x 15" triple granite-roller mills. A 25 h.p. electric motor drives the whole plant and direct chain gear-

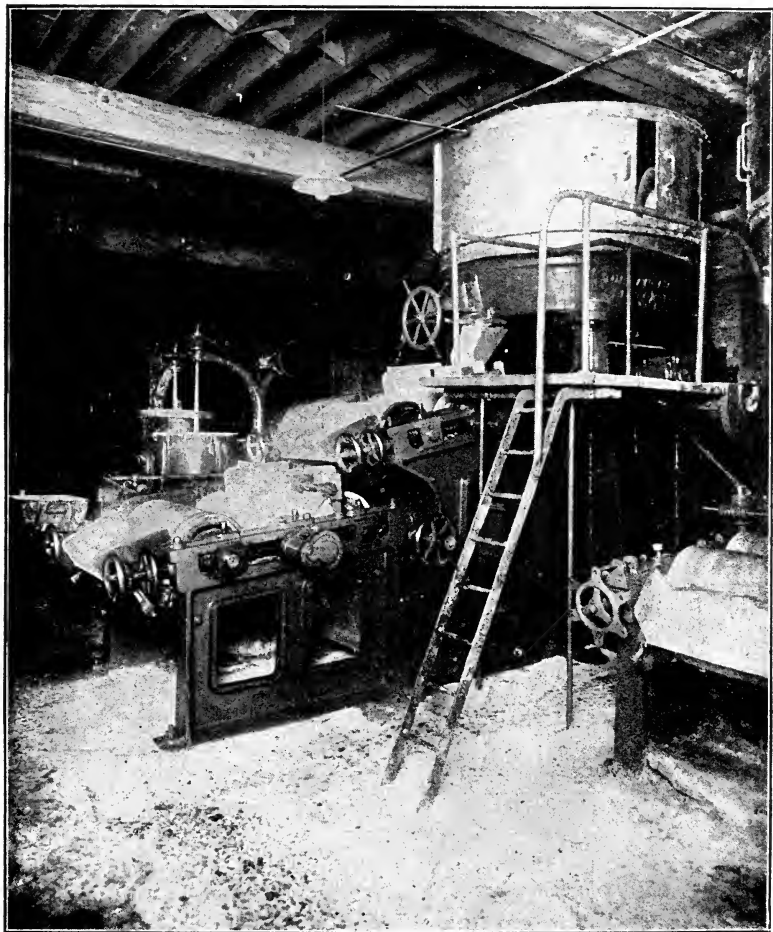


FIG. 52.—Electrically driven "combination" plant.

ing conveys the power to one or more of the three elements as may be required. In electrically driven plant of this nature provision should always be made for the mill-man to stop the plant instantaneously by means of a lever or cord

attached to the rheostat of the motor. An ammeter is also a desirable adjunct, as by it careless or improper handling of the plant can be readily checked and uniform and economical working promoted.

Before we leave the subject of roller mills reference must be made to what may be termed "multiple roller mills," that is horizontal roller mills containing more than three rollers. More or less complicated plant of this description has afforded a fruitful field for the inventive energies of a number of people, but as the theory of grinding has become better understood the opinion of practical men has set steadily in favour of the simplest type, the triple-roller mill. There is one very clear reason for this. It is founded on an appreciation of the fact that under ordinary conditions the best grinding results are obtained when the differential speeds of any two rollers in contact are 1 : 2. If we take the revolutions per minute of the front roller at as high a figure as 120, and this speed is permissible only in certain cases, we find that the revolutions per minute of the back roller will be 30. But if there were six rollers in the mill with a differential speed of 1 : 2 throughout and if the revolutions per minute of the front roller were 120, then the revolutions per minute of the back roller would be 3.75 and we should have a mechanical monstrosity.

Double or triple grinding through the same mill is not an ideal procedure although it is done to a great extent. It does not tend to economy in working. The ideal system is to make the whole process of paint-making as nearly continuous as possible, and this system is best carried out in the case of large works in which the output is large and regular by passing the ground pigment from mill to mill until it has received the requisite amount of grinding. If in any part of the processes of mixing, grinding or thinning one part of the plant is waiting for another, there is a flaw somewhere in the organisation and perfect economy is not being secured.

Flat-stone Grinding Mills.—Reference has already been made to the old flat-stone type of mill which was at one

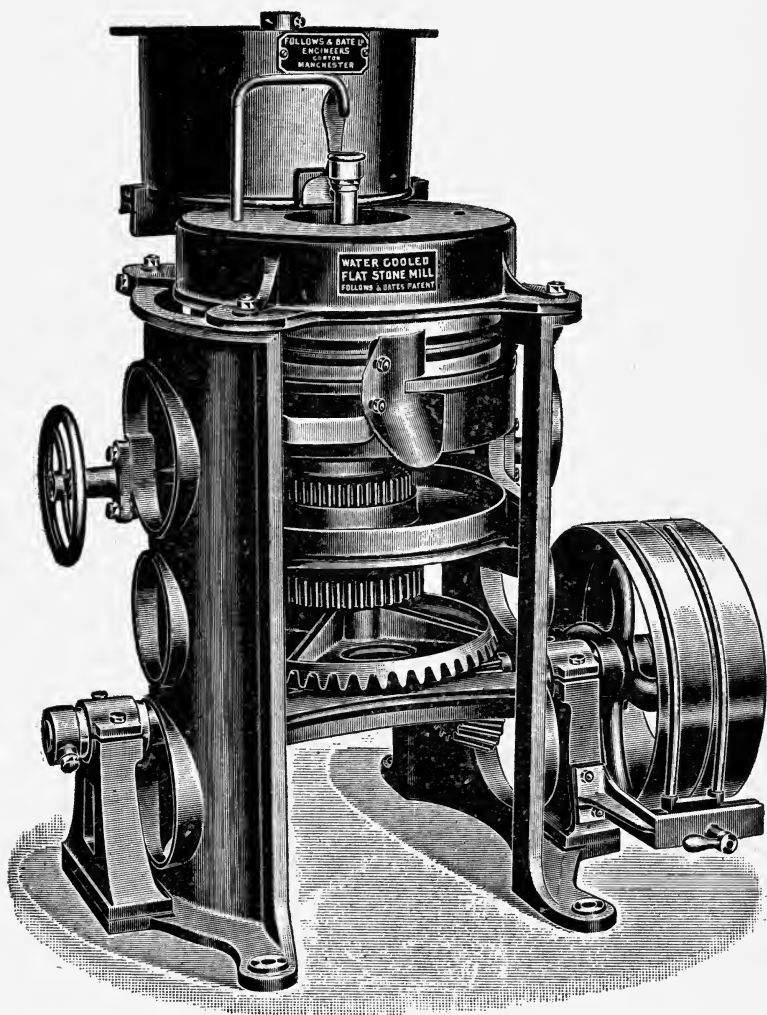


FIG. 53.—Water-cooled flat-stone mill for fine colours.

time the only form of grinding plant in use in the paint and colour industries. The small output, high power required and other obvious disadvantages have resulted in this type

of grinding becoming obsolete. Nevertheless in view of the mechanical efficiency of the flat-stone type, many people have clung to the belief that provided the principle could be adapted to suit modern conditions a mill could be evolved which would be useful for many purposes, particularly the

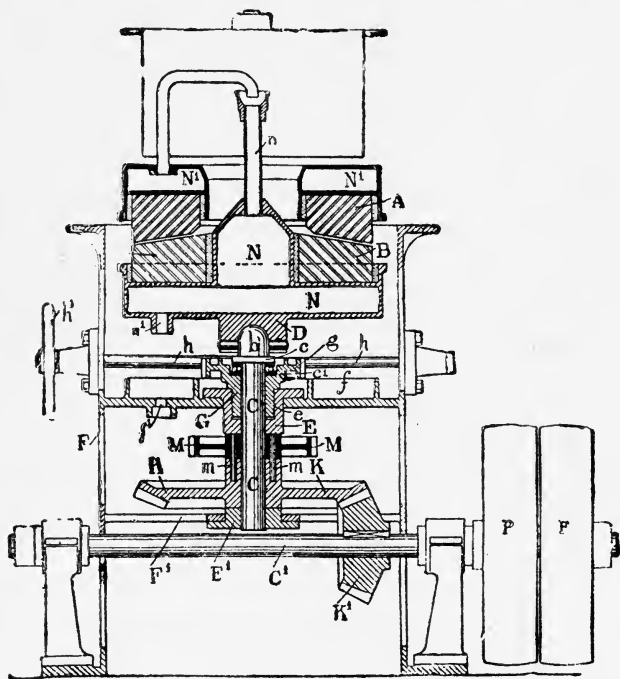


FIG. 54.—Sectional diagram of water-cooled flat-stone mill.

A, upper grinding surface; B, lower grinding surface; C, vertical; steel driving spindle; D, lower stone casing; E, e, G, vertical adjustable bearings for spindle; N, N', section of water chambers at back of upper and lower grinding surface; K, K', bevel driving gear; M, spur wheel driving back shaft carrying beaters of mixer; H, h', worm adjustment shaft and handwheel for raising or lowering grinding disc.

grinding of pigments in various mediums, to produce very fine pastes or pulps.

As a result of improvements extending over many years we now have the *water-cooled flat-stone grinding mill* which is illustrated in Fig. 53. This type of mill enjoys a wide use in America, and is used to no inconsiderable extent in

this country. A section of the mill is shown in Fig. 54. Both the top and bottom stones are in contact with a water-cooling arrangement which keeps the stones from becoming overheated, and prevents evaporation of volatile medium and discoloration of the ground product. The stones are usually of hard, close-grained granite, but the latest mills of this type have grinding surfaces of a special material which is likely to increase the efficiency of the machine and reduce wear and tear. Patent mechanical adjustments keep the stones in accurate contact and there is a worm gear and ball thrust bearing under the runner or bottom stone.

This mill is specially adapted for finishing the finest grades of paste colours such as artists' tube colours and coach colours in oil, gold size or other mediums. The cost for labour is very low, as one man can operate a gang of several mills.

In the designing and perfecting of paint plant there is no such thing as finality. The goal of yesterday is but the starting point of to-day, and the grateful thanks of the paint trade are due to those engineers who have devoted their specialized knowledge and skill to raising the standard of design and finish of these mechanical appliances which are so necessary to the paint manufacturer, and without which he would be seriously handicapped in meeting the demands of the present day.

PART III.

CHAPTER V.

THE GRINDING OF WHITE PIGMENTS.

THE expression *paint-grinding*, as generally understood, means the mechanical process whereby a pigment is converted into a paste by admixture with some fluid medium, which may be oil, spirit or water, or some modification of any of these, the mixture of pigment and medium being ultimately treated in one or other of the grinding mills which have already been referred to. The process therefore usually consists of two distinct stages—(1) mixing, (2) grinding, although in certain types of machinery (as for example the positive-driven edge-runner) the two processes may, in certain circumstances and in connection with specific grades of material, be combined.

The old conception of paint-grinding was reduction in the size of the particles, but present-day ideas tend in the direction of regarding mere reduction in the average size of the pigmentary particles as only one of the essential purposes of the operation. Perfect and uniform admixture of the pigment and the medium is now regarded as at least equally important, the more so by reason of the modern developments in the manufacture of mixed paints, the properties of which depend very largely on the degree to which perfect amalgamation between the ingredients of the stiff paste has been effected.

Hence in actual practice the process of grinding cannot be considered apart from that of mixing, and there is no more fruitful field for the application of the combined skill

and experience of the practical paint grinder and the paint machinery expert than in the designing for the treatment of different classes of pigment plant which will be most effective and economical for the double purposes of mixing and grinding. In this connection it should never be forgotten that specialization spells success. The plant and methods which are applicable to the grinding of whitelead may not and probably will not be equally suitable for the grinding of oxide of zinc, and a process which yields excellent results in the case of a pigment or mixture of pigments which requires 15 per cent. of oil to convert it into a paste, will in all likelihood be inapplicable if a pigment which requires 80 per cent. of oil is in question.

Another point which should always be kept in mind is the purpose for which the product of the paint-grinding process is intended. Thus, to take a simple instance, entirely different procedure in respect of nature of grinding medium and degree of fineness should be adopted when earth colour such as ochre, sienna or umber has to be ground for use as a painter's staining colour and as the base of an enamel paint respectively.

In this and the following six chapters practical notes based on experience are given, but it is well to point out that raw materials vary so widely, and the requirements of modern paint-making are so diverse, that those who control the paint-grinding departments of works must be constantly on the alert in order to deal effectively with chemical or technical problems and with mechanical and practical difficulties should these arise, as they undoubtedly will. Technically perfect paint-grinding is the idea which should be before every one who aspires to manufacture paints and enamels which are worthy of these much abused names.

1. THE GRINDING OF WHITELEAD.

The term whitelead is applied exclusively to the commercial white hydrated carbonate of lead, and the grinding of this

substance into paint forms a considerable part of the routine of many paint-works. Attempts have been made to argue that "white" is merely a descriptive adjective prefixed to the generic word "lead," and that any compound of lead which is white and which can be used as a pigment can be described as "whitelead". This view appears to open the door to fraud or misrepresentation and it is difficult to see how it could be upheld. The ordinary user or purchaser of paints and pigments has from time immemorial regarded "whitelead" as a single descriptive title which is applied to a material of comparatively definite composition, with the nature and properties of which he has become familiar.

Certain points in the chemistry and technology of whitelead have a direct bearing on the grinding of the pigment; no apology therefore is needed for referring to them in the present case.

Whitelead as it reaches the paint grinder is, in the majority of cases, a substance approximating to the composition represented by the formulæ $2(\text{PbCO}_3)$, $\text{Pb}(\text{OH})_2$, which is equivalent to a percentage composition as under—

Plumbic oxide (PbO})	. . . . .	86.32
Carbon dioxide (CO_2)	. . . . .	11.36
Water of hydration (H_2O}).	. . . . .	2.32

A comparison with the percentage composition of the normal carbonate (PbCO_3) is instructive—

Plumbic oxide (PbO})	. . . . .	83.52
Carbon dioxide (CO_2)	. . . . .	16.48

Careful analysis of a large number of dry samples, and a study of the quality of paint produced by each, has led to this conclusion, that if the composition varies much from the first of the above standards the result will be unsatisfactory. It may be found convenient in examining various samples, or in comparing results of their analysis, to treat the carbon dioxide (CO_2) as a measure of the variation from the standard, and the limits the author would suggest are 10 per cent.

and 11.5 per cent. That is to say, samples of whitelead which contain less than 10 per cent. or more than 11.5 per cent. of this component will *probably* prove to be inferior. An increase in the proportion of CO_2 indicates a lessened proportion of hydrated oxide ($\text{Pb}(\text{OH})_2$), which results in a pigment that will not bind well with the oil, while a decrease in the proportion of CO_2 indicates that the hydrated oxide is above the normal in quantity, and the result will be loss of opacity and inferior colour.

Whitelead that has been thoroughly washed in the manufacturing stage should contain no trace of acetic acid or acetate of lead. At first sight it might appear to be impossible for free acetic acid to exist in presence of a basic carbonate, but that the acid is present in badly prepared samples of the pigment is capable of the simplest experimental proof. Acetic acid, when present, is most probably due to the decomposition of the acetate, which dissociates at ordinary temperatures. The presence of acetate of lead should always be tested for before grinding, as its presence has a most prejudicial effect on the paint, causing it to harden to an abnormal extent. The characteristic smell of acetic acid can sometimes in extreme cases be detected when whitelead is being ground in oil, the heat generated by the rollers causing the basic acetate of lead to evolve free acetic acid.

Different makes of dry whitelead vary in regard to the softness of their particles. This property may be tested by placing a few drops of turpentine on a little of the dry powder, and rubbing the mixture with the finger on a porcelain slab. It should be borne in mind that whitelead with hard particles requires very careful grinding; it may even be necessary to pass the paint twice through the rollers, whereas one grinding is usually considered sufficient.

There should be no moisture in a well-finished whitelead, but by adding, during the mixing of the lead with the oil, a small proportion of fine, pale soft soap (say .1 to

·2 per cent. on the weight of dry lead), it is quite possible to grind whitelead containing an appreciable amount of moisture. This procedure is not to be recommended, on obvious technical grounds, and must be regarded as a wrinkle of the practical paint-grinder who may be called on to deal with a defective parcel of pigment.

During recent years the practice has been adopted largely among whitelead corrodors who grind their own whitelead in oil of doing away with the final drying of the whitelead pulp as it comes from the washing process, and grinding or beating up the pulp (exhausted of water until the proportion of the latter does not exceed about 20 per cent) with a suitable quantity of refined linseed oil. This process depends on the greater surface attraction which whitelead particles offer to linseed oil than to water. It enables considerable economies to be effected in the manufacture of "ground whitelead" and it eliminates risk of lead poisoning during one of the most dangerous parts of the whitelead manufacturing process. Nevertheless "ground whitelead" prepared in this way is in the opinion of the writer open to grave objection. A full discussion of the subject is, however, outside our present scope.

The colour of whitelead has an important bearing on its commercial value, and the more nearly it approximates to absolute white (which is total absence of colour) the better. It is a fallacy to suppose that the addition of a small quantity of blue, which is sometimes added to "kill" the yellow shade, really increases the absolute whiteness. Commercial whitelead varies in respect of colour to a much greater extent than most people imagine.

On the opacity of a given sample will depend, in a large measure, its value for the purpose of paint-making; hence the determination of this property is most important. It has been observed that the more crystalline the particles are, the lower is the opacity. For this reason whitelead made by the chamber process and by certain other processes

have not, as a rule, so great an opacity as that made by the stack process. To determine the opacity, a rough-and-ready way is to take equal weights of the whitelead under examination and a standard sample, to mix each thoroughly with equal weights of oil, and to paint a blackboard with the mixture. The sample that most completely masks the colour of the ground-work has the greater opacity. The method is not a reliable one, owing to the difficulty of ensuring that the films of paint are of exactly equal thickness. For remarks on the exact determination of this property reference may be made to Chapter III.

Finally, a point that the lead grinder would do well to take note of is the age of the whitelead. There is no doubt that ageing for a few months before grinding results in an improved texture being communicated to the ground product. The changes which take place are partly chemical and partly physical, and need not be entered on here. Again, a mixture of two or three different makes of whitelead have been found to yield a better product than that obtained from any of the whiteleads ground alone.

To summarize the preceding paragraphs, the points that should be noted in whitelead in order to estimate its value for paint-making are—

(a) Percentage composition (of which the proportion of carbonic acid gas (CO_2) is a fair criterion).

(b) Presence of moisture and soluble lead salts (the latter indicated by an acid reaction when some of the pigment is digested in boiling distilled water).

(c) Softness.

(d) Colour.

(e) Opacity.

(f) Age.

As there are few pigments that have a greater chemical action on the medium in which they are usually ground—namely linseed oil—than whitelead, it will not be out of place to consider somewhat carefully what reactions occur

when the pigment is ground in that medium. Taking into consideration the short space of time during which the whitelead and oil are in contact with each other during the processes of mixing and grinding, we may consider the stiff paste as it leaves the rollers to be a mechanical mixture of whitelead and oil, in which the individual particles of the former may be considered as surrounded each in an envelope of oil. The hydrate part of the whitelead ($\text{Pb}(\text{OH})_2$) gradually saponifies a portion of this oil, and the lead soap so formed constitutes a binder holding the carbonate part (PbCO_3) in suspension. Each particle of whitelead is therefore the origin and centre of a chemical and absorptive action on the oil, the quantity of which must be sufficient to permit of this action being carried to its practical limit, and still leave enough unacted on to keep the whole mass at the consistency of a paste. Ground whitelead that has been ground with an insufficient quantity of oil will often be found to contain numerous more or less completely dry particles; in other words, the oil was not sufficient to satisfy the internal chemical changes. An important practical point follows from this, namely, that unless very thorough mixing of the oil with the whitelead has taken place before, the mixture reaches the rollers there is considerable risk of the paint becoming lumpy and hard in portions, because if the rollers happen to crush a lump of *dry lead* the oil will be deficient in the paint at that spot.

The preceding paragraph also furnishes an explanation of what is known as the *ageing* of ground whitelead, which in practice amounts to this: that the chemically active part of the whitelead has saponified a portion of the oil, the whole mass has become stiffer and tougher and binds together better, and, as the painter very soon finds out, there is a great improvement in the manner in which the paint works under the brush.

The Process of Mixing previous to Grinding.—As has been already indicated this is a most important stage, and

too much care cannot be taken that it is efficiently carried out. Opinions differ as to what is in theory the best form of mixing machinery. The open-pan or edge-runner type of mill is recommended by some authorities, while others still adhere to the vertical pug-mill. The former is applicable if a fairly large proportion of oil is used in the mixing, but is not so satisfactory when the product is required in a very stiff form. The prevention of dust is a point that must be borne in mind when installing plant of this nature, and the whole matter requires careful consideration in view of the circumstances peculiar to each case. Here is one of the instances in which full discussion with competent paint engineers is imperative before the precise type of plant is finally decided upon. For practical utility the vertical pug-mill can be recommended in many cases. It can be made of any size or strength, while the working parts are simple and can be easily removed for cleaning and repairing. Owing to internal friction, due to the high specific gravity of lead and the small proportion of oil in which it is ground, care must be taken that undue heat is not generated in the contents. With care on the part of the workmen, and by attending to the points in construction detailed below, this will be avoided.

The *working depth*, i.e. the height inside to which the full charge will reach, should not exceed the diameter. If it does so to any extent, heating at the bottom is very likely to occur. Charges exceeding 20 cwt. in weight are seldom quite satisfactory; the dimensions therefore of a pug-mill suitable for this quantity of whitelead may be taken roughly as 32" deep by 28" in diameter. A pair of pugs elevated over the rollers so as to discharge their contents directly on to the latter will usually be found most convenient, and in this case the slide doors are best placed at the bottom, and made to open either by a lever arrangement or by a screw. For whitelead mixing the form of pug-mill indicated in Fig. 39, namely the under-driven variety, possesses the great

advantage that in it provision can be made against the dissipation of lead dust. In the over-driven form this is much more difficult to accomplish, as the spindle and gearing prevent perfectly tight joints being made. The under-driven type of machine has fallen into some disrepute among paint grinders, chiefly perhaps because, in the case of separate mixers placed on the floor level, the gearing below the pug became a source of annoyance and trouble, and was found to be liable to become clogged with paint. Great improvements have been effected in the design and structure of mills of this class during recent years, and when suitably adapted to meet the necessities of the case, the combination of under-driven pugs and grinding mill shown in the illustration referred to above is well worth attention.

Good results can be obtained from edge-runners either of the old two-stone type or of the more recent *positive-gear*ed form. The objections to the old-fashioned open-pan type of mixing mill for whitelead are twofold. First, they do not turn out the same amount of work in an equal space of time and with the same labour as pug-mills ; and secondly, owing to the large surface area, the danger from dust is augmented. Pan-mills, however, possess undoubted advantages in certain departments of paint-grinding, which will be dealt with in their place.

It must not be supposed that because the form of plant described in the foregoing has been dealt with in some detail other forms are without merit. All that is attempted here is to indicate a method of mixing which in the opinion of many people qualified to judge is capable of yielding good results. The horizontal type of mixing mill (Fig. 25) may be used to mix whitelead with oil in cases in which the oil is present in fairly large proportions. This type of mill, however, is quite unsuited for very stiff pastes, the tendency of the spindle and base of the knives to become clogged being a point against it. Another point is that with an adhesive substance such as a mixture of oil and whitelead,

a considerable "head" or weight above the point of delivery is necessary to prevent a considerable portion of the charge remaining in the pug.

Very efficient mixing is accomplished by the more modern positive-driven type of edge-runner, and if a complete installation consisting of mixer and grinding mill is erected a "combination plant" is obtained which is very nearly continuous in its action. The prime cost is considerable; hence the type is particularly suitable for large works in which huge quantities of materials have to be handled. The special features of this highly specialized form of mixing and grinding plant are dealt with in the section devoted to machinery.

The Process of Grinding.—The only type of grinding mill which is of practical importance in connection with the grinding of whitelead is the triple granite-roller mill. The construction and special features of this mill have been discussed fully in a previous chapter, and we may therefore confine ourselves here to such points as relate particularly to the grinding of whitelead.

The rollers should be massive, and capable of being subjected to considerable pressure, whitelead being a pigment which though soft in itself requires a tight-set roller to produce good paint. This question of pressure on the rollers is an important one, and every practical paint-grinder knows that the pressure, both on the back and the front rollers must be varied to suit the particular pigment which is being ground as well as the nature and proportion of the grinding medium. It is more often than not left entirely to the discretion of the workman to screw up his rollers at his own sweet will. Not being acquainted with the mechanics of the screw, he often errs in the direction of subjecting the rollers to a quite needless pressure, with the result that a breakage becomes more likely to occur than would otherwise be the case. After prolonged running the rollers become heated to a considerable extent, and owing to the crystalline

nature of granite each roller when heated may be regarded as being in a state of strain. A slight jar in these circumstances is sufficient to cause a fracture. A mill should never be started while the rollers are screwed tightly together, and only men of known skill and experience should be permitted to "set" or alter the tension on the rollers. The adoption of the parallel adjustment (one form of which was described on p. 69) is much to be recommended.

The great point to aim at in lead grinding is to avoid the generation of undue heat and at the same time to produce a well-ground paint, and the conclusion to which one is driven is that with thoroughly well mixed material a triple granite-roller mill can do all that is required of it provided it is properly handled.

It is still debated whether a lateral motion on the middle roller is an advantage. Great improvements in this department of mill construction have been effected, and there can be no doubt that considered from the point of view of efficient grinding, and from that of wear and tear of the rollers, the most modern type of lateral movement is to be recommended. The old-fashioned "snatching" movement was quite inefficient and is now entirely superseded.

It cannot be too strongly urged on manufacturers to endeavour by means of an efficient system of ventilation and other precautions to ensure that the dangers arising from handling whitelead are reduced to a minimum. A suitable arrangement of air-shafts and fans is imperatively necessary if the baneful effects of whitelead dust, and the disagreeable, if not actively injurious results due to volatile products generated in the process of mixing and grinding, are to be avoided.

Oil in Whitelead Grinding.—Only refined linseed oil is used in England for whitelead grinding, and it is of paramount importance that the refining process is properly conducted, and that no traces of moisture or mineral acid remain in the oil. Free fatty acid is usually present in refined linseed

oil in proportions varying with the age and method of treatment. If it is present in excess there is a probability of the paint being injuriously affected. Were it not for the yellow tint it communicates to the paint, well-tanked raw oil might be substituted for refined linseed oil, but it would be necessary to ensure that all albuminous matter had been deposited. On the Continent poppy oil enjoys a considerable use in whitelead grinding. The drying properties of this oil are feebler than those of linseed oil, and for this reason it is more suitable for use with certain Continental makes of whitelead, which are sometimes liable to give rise to a hard or brittle product when ground in the English manner. The quantity of oil required varies greatly. The best makes of English stack-made whitelead can be ground with as little as 70 to 77 lb. of oil to 10 cwt. of dry lead say ($6\frac{1}{4}$ to $6\frac{3}{4}$ per cent) although this yields a very "stiff" ground whitelead. On the other hand some foreign makes require as much as 93 lb. of oil for the same weight of dry lead (say $8\frac{1}{3}$ per cent). In general terms it may be stated that whitelead of good average quality should be capable of yielding a satisfactory paint when ground with 7 per cent of linseed oil. The percentage composition of the paste will therefore be:—

Whitelead	.	.	.	.	.	93.46
Refined linseed oil	.	.	.	.	.	6.54
						<hr/>
						100.00
						<hr/>

Ground whitelead that is intended for use in mixed paints of good quality should never be ground less than twice, and the proportion of oil which is employed in the grinding should not be cut unduly low. In this case $7\frac{1}{2}$ to 8 per cent. on the weight of dry pigment will probably be about right.

2. THE GRINDING OF OXIDE OF ZINC.

No pigment has come into greater prominence within the last decade than oxide of zinc; indeed it may be said

that not a few of what were at one time conventional ideas regarding this pigment have been revolutionized. The immense increase which has taken place in the use of enamels and enamel paints has compelled paint manufacturers to devote special attention to oxide of zinc, the special properties of which confer on it a peculiar interest in this connection. Furthermore the chemical technology which underlies the manufacture of the pigment itself has been studied closely, with the result that there is at the disposal of every paint manufacturer, a mass of authenticated information which enables him to differentiate between different makes and brands, and to select the one which is most likely to be of service to him in connection with the special purpose he has in view.

It would be advantageous if the terms "zinc white" and "white zinc" were deleted from precise trade nomenclature. The expression "zinc white" has crept into use as descriptive of another pigment, lithopone, the nature and properties of which are in many respects entirely different from those associated with oxide of zinc, and consequently it is difficult at the present time to assert with confidence whether the description in question can be held to apply to a definite pigment or mixture of pigments. Hence the suggestion is advanced that when the description "zinc white" is used, it should be amplified or explained by a clear indication of the composition of the material so described.

A clear distinction should be drawn between the two commercial varieties in which oxide of zinc is found on the market at the present time. One of these is produced by the volatilization and combustion of metallic zinc (spelter) while the other is obtained in a somewhat similar manner but direct from the zinc ore, the intermediate production of metallic zinc being done away with. Oxide of zinc obtained by the latter process has come to be described in the trade as "direct oxide of zinc".

The fundamental difference between the products of the

two processes is that whereas commercial oxide of zinc produced by the historic method from spelter contains from 98 to 99.6 per cent of real oxide of zinc (the balance consisting of small quantities of metallic impurity), direct oxide of zinc contains as a rule only 95 to 96 per cent of real oxide of zinc, the remaining 5 to 4 per cent consisting of what is usually described as "basic sulphate of lead," that is normal lead sulphate (PbSO_4) associated with a variable proportion of lead oxide (PbO).

According to the purpose for which the oxide of zinc is to be used this lead compound may be advantageous or the reverse. It does not fall within the scope of this work to discuss the relative merits of the two varieties of oxide of zinc; recent technical literature provides ample data for determining which of the two types is likely to prove most satisfactory for a particular purpose. As the rules to be observed in the processes of mixing and grinding are the same for all varieties and grades of oxide of zinc, no special reference to either of the two classes are made in the following paragraphs, but the subject is of interest in connection with the matters referred to in the chapter which deals with enamels.

Oxide of zinc exerts little drying action on linseed oil, therefore when it is ground in that medium the conditions that obtain cannot be compared with those already treated of in the case of whitelead. The drying of paint containing the pigment now under consideration depends largely on the siccative nature of the medium in which the oxide of zinc may be considered as mechanically suspended. Oxide of zinc, however, combines very readily with most of the true resins, which are acid bodies. This affinity has a bearing on the manufacture of enamels, and advantage is taken of it in certain circumstances that will be referred to later.

The points that should be attended to in determining the value of a sample for paint grinding are—(1) *Colour*, which should be a pure and brilliant white. There must also be included the capacity to retain this whiteness per-

manently after the pigment has been mixed with oil. This at once separates a number of second-rate grades, which, though apparently of good colour when dry, gradually turn yellow when converted into paint. When separate portions are rubbed out in water with minute quantities of Prussian blue and chrome yellow respectively, no greenish shade should be observable in either mixture. (2) *Perfect dryness*. Owing to its powdery and voluminous nature oxide of zinc exposes a large area to the influence of adventitious moisture. Storing in a damp warehouse, for example, will cause it to absorb a noticeable proportion of moisture, and the presence of the latter is quickly observable in the grinding process. (3) *Freedom from deleterious impurity*. Since the manufacture of oxide of zinc depends on combustion processes, impurities in the metallic zinc or the ore of necessity find their way, to some extent at least, into the deposited oxide. What constitutes "deleterious impurity" will depend on the purpose for which the paint is required. It would be foolish, for example, to use an oxide of zinc containing even minute traces of lead compounds as an ingredient of an enamel which was to be used on the walls of a chemical laboratory. On the other hand 4 per cent. of combined lead compounds might constitute a valuable ingredient if the paint was to be used as an exterior protective agent. (4) *The texture of the powder*. The particles should be uniformly fine and amorphous.

There are considerable differences in the oil-absorbing properties of different samples of oxide of zinc. A hard flinty pigment will cost much more to grind than a soft absorptive one and will not produce such good paint. In all such matters constant laborious testing and taking nothing for granted are golden rules.

The Process of Mixing previous to Grinding.—Experience has proved that it is of the greatest importance to keep the mixture composed of pigment and oil as cool as possible. Oxide of zinc, although in the dry state an ex-

ceedingly light and powdery body, yields a very cohesive mass when mixed with oil. Consequently undue heating due to mechanical friction is liable to occur during the mixing process, and this at once leads to discoloration of the paint, and has moreover the effect of causing the paint to pass through the rollers of the grinding mill in a very unsatisfactory manner. The difficulty here indicated has been accentuated owing to the growing habit among paint grinders of using the minimum quantity of oil.

The positive driven edge-runner type of mixer is probably the most satisfactory, the tendency towards heating being in it reduced to a minimum. It has the further advantage that by exerting a more or less prolonged grinding action of a partial but none the less noticeable character the oil is ground into the pigment before the mixture reaches the grinding mill. It is well to note here that the affinity of oxide of zinc for linseed oil and water respectively is just the opposite of whitelead. Oxide of zinc tends to cling to water and to repel oil. Hence the rule that ground oxide of zinc should never be covered with water.

The mill may be elevated above the floor level so as to discharge directly on to the grinding mill. The procedure in mixing the pigment with the oil in a pan mill is somewhat different from that usually adopted when the mixing is conducted in a vertical mixer. To obtain the best results in the shortest space of time, about three-fourths of the oil should be placed in the pan first, as much as possible of the pigment is then added gradually so as to produce a stiff paste, the mill running all the time, and the balance of oil and pigment carefully added in alternate portions. If the whole charge is placed in the pan at once a large proportion of it will probably escape over the lip of the pan and the power consumed in driving the mill will be enormously increased. Sixteen to twenty revolutions of the runner round the pan per minute is a high enough speed, and the slower the speed the better, consistently with effective and economical working.

The Process of Grinding.—In the grinding process the pigment, after being mixed with the oil in the manner indicated above, is passed through a triple granite-roller mill of the ordinary type. Owing to the viscous nature of the mixture of pigment and oil massive rollers should be used, 30" × 15" being the favourite size. A suitable form of combination plant is shown on p. 81. For the best qualities of paint repeated grinding is to be recommended, and if the stiff paint is intended for use in enamels four or even five grindings may be necessary. In consequence of the density of the paint being lower and the viscosity greater than in the case of lead, the quantity which passes through the rollers in a given time will be less than in the case of the latter substance. A mill capable of turning out 4 tons of ground whitelead in $9\frac{1}{2}$ hours may be supposed capable of turning out about $2\frac{1}{2}$ tons of ground oxide of zinc in the same period.

Oil Used in Grinding.—The oil used in grinding oxide of zinc is refined linseed oil, and in the case of the best grades of pigment from 10 to 12 per cent. of oil will be required to make a paste-paint of the proper consistency. In other words, 10 cwt. of pigment will require from 134 to 157 lb. of refined oil. Even lower proportions of grinding medium are now used, and the exact quantity will depend on the nature of the medium and the purpose for which the paste-paint is required. If the paste-paint is to be sold just as it is it will seldom be passed through the rollers more than twice, in which case 12 per cent. of oil (or in the case of some brands of oxide of zinc even a higher proportion) will be required. On the other hand, if the paste is to be employed as the base of high-grade paints or enamels, it will probably be ground three or four times, and in this case owing to the more perfect assimilation between the pigment and the oil a smaller proportion say (10 per cent.) of the latter will suffice. An important factor in such matters is the size, weight, and efficiency of the mixing and grinding

plant, and as a general rule lower proportions of oil are employed now than in years gone by. Some makers use an extra-pale boiled oil (such as that made by the Hartley-Blenkinsop process), either alone or in conjunction with refined raw linseed oil. Others use refined oil with a small proportion of pale grinding varnish (say, 1 gallon of varnish to 8 gallons of oil). Others again employ refined oil alone. There is no doubt that much of the misconception which existed for many years in the minds of painters regarding oxide of zinc was due to their being supplied with the pigment ground to a stiff paste in refined oil alone. Problems connected with drying and the production of "flat finishes" from such a mixture beset the painter on every side. The modern paint maker has no excuse for following such antiquated methods.

There are some rather interesting and instructive theoretical considerations which have a practical bearing on this point, and which are worth noting in connection with the grinding of oxide of zinc. First, looking at the *physical* or mechanical side of the question, apart from the *chemical*, we must remember that we are dealing with a mixture of oil and pigment containing practically one and a half times the proportion of oil contained in ground whitelead. Now the conditions that we strive to obtain between any two rollers of a grinding mill are diametrically opposed to those that exist in the case of an oiled journal and its bearing. In the former case, we want as much friction as we can get, so long as the stones do not press too heavily on one another. By using a viscous oil such as pale-boiled oil, we are keeping the rollers apart and are retarding friction and impeding grinding. On the other hand, by using a fluid oil, such as refined linseed oil, alone, two results follow: sufficient paint is not admitted between the grinding surfaces, with the result that undue wear and tear occurs, and the output is materially reduced. The practical conclusion arrived at is that a small proportion of thick-bodied oil or varnish assists

the grinding process, but that too large a proportion actually retards it, and this will hold good for all pigments that require a large proportion of oil in order to reduce them to the consistency of stiff paste in the grinding process.

Turning to the chemical side of the question, we know that zinc oxide has but little if any action on linseed oil, but that it possesses a strong tendency to form compounds with the resins. The use, therefore, of a small quantity of varnish has the effect of maintaining a proper consistency in the paint so that after it has been ground for some time it can be cut out in a stiff homogeneous paste. Oxide of zinc stiff paint which is of poor quality or indifferently ground will usually be found, after keeping, to turn soft and "sloppy". Hence to summarize the above it may be said that both theory and practice point to the advisability of using refined linseed oil in which has been incorporated about 10 per cent of a suitable grinding medium the exact nature of which will depend on the results that are aimed at.

It has already been remarked that oxide of zinc has a marked affinity for the resins. Use is made of this property in the manufacture of certain enamels and special paints such as ships-bottom compositions, etc., in a large number of which oxide of zinc is the pigment basis. When a glass-like surface is aimed at in the finished product, as in the case of enamels, absolute perfection in the grinding process is essential, otherwise the product, when thinned out ready for use, will be sure to have a gritty appearance. In grinding for this purpose therefore all considerations of time must be treated as of secondary importance, and perfect finish must be looked upon as the *sine qua non*.

In short, under modern conditions the mixing and grinding of oxide of zinc may be regarded as one of the most specialized departments of paint-grinding. Nothing can be left to chance or rule of thumb if the best results are aimed at. In reality it constitutes the first stage in what has

become a new industry during the last ten or fifteen years—the manufacture of enamels and enamel paints.

3. THE GRINDING OF LITHOPONE.

The complex pigment consisting of approximately molecular proportions of zinc sulphide (ZnS) and barium sulphate (BaSO_4) and produced by the simultaneous precipitation of these two compounds from watery solutions constitutes an important member of the class of raw materials used by the paint manufacturer. Great ingenuity and much subtle imagination have been devoted to the invention of names and descriptions for this pigment, but simplicity will be promoted if we refer to it here simply as lithopone. For the reasons stated in the last section the description “zinc white,” though often used, is open to objection. The composition of the pigment is usually expressed in terms of the ZnS content, 29 to 30 per cent being the recognised normal proportion of this component, the remaining 71 to 70 per cent consisting of precipitated barium sulphate. The presence of zinc sulphide in proportions greater than 30 per cent does not improve the pigmentary properties of lithopone for paint-making, but for certain other technical applications a higher ZnS content is sought for.

Lithopone provides a striking commentary on the principle that the value of pigments for the purpose of paint manufacture depends quite as much on their physical condition as on their chemical composition. Here we have a pigment which possesses great opacity and many excellent paint-forming properties, which nevertheless consists of two materials neither of which is of value to the paint maker by itself. Not less remarkable and instructive are the physical differences between native sulphate of barium (barytes) and precipitated sulphate of barium. These will be referred to in their proper places.

The Mixing and Grinding of Lithopone.—The plant which is usually employed is the same as that used for the

mixing and grinding of oxide of zinc. The specific gravity of lithopone is less than that of oxide of zinc, being as a rule 4.26, whereas oxide of zinc possesses a specific gravity of from 5 to 5.6 according to the grade. The bulk of a given weight of dry lithopone is, however, much less than the bulk of the same weight of oxide of zinc; consequently lithopone is not so troublesome to mix as oxide of zinc, particularly during the early stages of the process.

Ten per cent of refined linseed oil (calculated on the dry pigment) is a fair average of the quantity of oil required in grinding the pigment. Very much better results are obtained (particularly if the paste-paint is intended for use in mixed paints) if instead of using all refined linseed oil in the grinding a portion of the latter (say 5 to 10 per cent) is replaced by a suitably compounded drying medium.

Different brands and makes of lithopone present enormous differences in respect of their behaviour when ground in linseed oil. Some prove to be most unsatisfactory yielding a paste which "feeds up" and becomes tough and stringy. This is in most cases due to the presence of minute traces of chemical impurity in the pigment, and those who propose to use lithopone largely are advised to make themselves familiar with the nature and properties of the brand they think of adopting before they make large purchases. At the present time there are few pigments which offer a wider scope for intelligence and technical skill on the part of the paint manufacturer than lithopone, but it must not be forgotten that conventional methods and practice must be modified if satisfactory results are to be achieved. Lithopone will be referred to again in the portions which deal with mixed paints and water paints.

4. OTHER WHITE PIGMENTS.

Basic Sulphate of Lead.—Attempts have been made during the last twenty-five years to introduce and popularize as pigments compounds of lead other than the hydrated

carbonate. The crystalline properties of the normal sulphate of lead (PbSO_4) among other features possessed by the compound have militated against its approval by the paint-grinding fraternity. Alleged improvements in the process of manufacture resulted in the introduction of what is variously known as "basic sulphate of lead" and "sublimed whitelead". On its first appearance this was described as "non-poisonous whitelead," but most reliable authorities refuse to concede to it the right to be described as "whitelead" and many people entertain grave doubts as to its non-toxic properties. Nevertheless the strictly technical features of the pigment are deserving of attention, as it is quite possible that used in conjunction with other pigments it may be found to possess merits for special purposes.

Leaded Zinc White.—This somewhat unsatisfactory trade name is applied to a series of complex pigments, more or less white in colour, which consist of about 50 per cent of oxide of zinc and about 50 per cent of sulphate of lead, a small portion of the latter ingredient being in the form of basic sulphate of lead. Up to the present time the type of pigment known as "leaded zinc" has not been much used, and further experience will be required to prove whether it possesses real technical value in comparison with existing pigments. The conjecture may be hazarded that there is a field for pigments of this class, inasmuch as they possess features which no adventitious mixture of oxide of zinc and basic sulphate of lead possesses.

Barytes.—Such enormous quantities of this pigment are consumed in the manufacture of certain grades of paint that a few remarks on its leading characteristics, and its behaviour during and after grinding, may not be out of place. In selecting barytes for admixture with whitelead or other white pigment special attention should, in the first place, be directed to the colour of the sample, not only in the dry state but also when rubbed down in refined linseed oil. The uniformity of the powdering is the second important

point, and the third is the behaviour of the barytes when actually ground in oil. The finest grades of white barytes require practically the same proportion of oil for grinding as whitelead. When, therefore, a mixture of whitelead and barytes is to be ground, the oil required may be estimated without serious error at 7 per cent. The lower grades of barytes require larger proportions of oil. Consequently the value of this article to the paint-grinder depends partly on this factor. As a rule paste paint containing an appreciable proportion of barytes tends to become soft when kept. In the popular language of the trade such paste-paint is said to "drop". The state of subdivision of the particles of barytes has a considerable influence in this connection, and it has been found that it is an advantage not to have the powder in too impalpable a state. When the particles of barytes are sufficiently large to enable the rollers to get hold of them, so to speak, they are ground into the lead better, and the properties of the latter override the properties of the former, to the advantage of the paint. These remarks apply especially to the grinding of "reduced whitelead," and are not of universal application.

The lower grades of barytes, which are used in cheap coloured paints, vary in their colour (impure white to grey or brown), composition (silica, iron, alumina, etc., being present), texture and behaviour on grinding. The lower the quality the larger the proportion of oil required. Thus a common barytes, such as might be used in very cheap black paint, will probably require about 10 per cent. of oil. This gives rise to the suggestion that it is not always the best economy to use very cheap barytes; for besides the extra oil consumed there has to be considered the extra grinding required, and the extra wear and tear on the plant. Large proportions of barytes are inadmissible in paste-paint which is to be converted into mixed paint as the barytes is extremely liable to settle out owing to its crystalline nature and its lack of affinity for oil.

Whiting and Paris White.—Powdered chalk (carbonate of calcium), which is known variously by the foregoing names, cannot strictly be called a *white* pigment; nevertheless it may be conveniently referred to here. From the paint manufacturer's point of view there are two main uses for this article—(1) It is a convenient cheapening agent, along with sulphate of barium, for admixture with coloured pigments, and (2) it is the basis of that widely used article, *glazier's putty*, and also to a less extent of many grades of the article known as *patent driers*. As an adulterant it is used for the most part along with barytes, its lightness and cohesive nature when mixed with oil tending to neutralize the weight and open texture of the barytes. In practice the relative proportions of barytes and whiting that are found most satisfactory in ordinary cases are 2 to 3 parts of barytes and 1 part of whiting. The use of too large a proportion of barytes will cause the paint to turn soft and to separate from the oil, while the whiting if present in too large quantity will on account of its opacity destroy the colouring power of the pigment. Ordinary whiting requires about 23 per cent of oil in grinding.

The best quality of putty is made of whiting (which should be free from moisture and caustic lime) and raw linseed oil. The ingredients are thoroughly incorporated under edge-runners, and are then usually transferred to a dry floor to "sweat" for a short time. The mass is finally worked up again with a little more oil and the putty is ready for use.

An important technical application of whiting which should not escape the attention of practical paint manufacturers is its value as a neutralizer of acidity in paints. It is not uncommon nowadays to introduce about 5 per cent (calculated on the total pigment content) of carefully selected carbonate of lime into paints which are intended for use as priming or anticorrosive coats on iron and steel. The alkaline carbonate serves the double purpose of neutralizing any

free acid which may develop in the paint itself, and of counteracting acidity which may be latent in the metallic surface.

China Clay.—The older race of paint-grinders regarded this material with a considerable degree of veneration, and many of the conventional formulæ for the preparation of paste-paints contain china clay as an essential ingredient. It is not regarded with favour nowadays except for special purposes, chief among which is its capacity, when properly used, of increasing the crispness and firmness of stiff paints. This property, which china clay shares in common with several other compounds of alumina, is taken advantage of in the grinding of pigments which absorb large quantities of oil, for example, ochres, siennas, and other earth colours. A small proportion of china clay added to the “mash” imparts a better physical appearance to the product. In the grinding of artists’ colours the physical appearance of the paste is of vital importance, and in the grinding of such materials a small proportion of phosphate of alumina is frequently found to be of value.

China clay should never be used with a water medium, and even when used in an oil medium should be employed sparingly and for specific purposes.

Gypsum.—This pigment which is also known as *terra alba* consists of the hydrated carbonate of calcium ($\text{CaSO}_4, 2\text{H}_2\text{O}$). From the strict technical standpoint the material can be regarded merely as a filler, extender, or cheapener of mixed paints and the most that can be said in its favour is that under certain conditions it does not materially reduce the efficiency of the paint. Owing to its special physical properties *terra alba* is used to a considerable extent for adulterating painters’ staining colours, especially siennas.

Talc.—Current paint literature contains references to “asbestine” which is a modern trade name for such grades of talc or soapstone as are suitable for use in paint making. Talc is an extremely interesting mineral, and although it is not

usually regarded as one of the standard raw materials in the paint trade, it finds a place in the formulæ of certain paints, and might possibly be utilized to a greater extent than it is. In composition it is identical with steatite or soapstone, but has a more crystalline structure. Chemists do not appear to be agreed as to the exact constitutional formula that should be applied to talc, but the following are typical analyses:—

	(1)	(2)
SiO ₂	62.077	62.27
MgO	33.126	30.95
FeO	0.104	0.85
Al ₂ O ₃	0.313	0.15
H ₂ O	4.286	4.84

Thus the material may be regarded as an acid metasilicate, with the empirical formula $H_2Mg_3(SiO_3)_4$, but other views are entertained by some chemists. When finely ground, talc enters into the composition of certain of the modern emulsion paints which are referred to later. The pigment is exceedingly permanent, and makes a good “filler” or “extender”.

Silica.—Quite a modern application of this material is its use for the purpose of communicating “tooth” or “bite” to paints. A paint which contains only 1 per cent of silica will work quite differently under the brush from one which is free from the material but is similar in other respects. Silica is typical of a large group of materials, minute quantities of which materially alter the ordinary properties of pigment. The unforeseen effects produced by mixing different pigments together will surprise only those who are novices in the science of experimentation.

CHAPTER VI.

THE GRINDING OF EARTH PIGMENTS.

THE group of pigments commonly known as that of the *earth colours* includes the ochres, siennas, umbers and Vandyke brown. Inasmuch as these find their principal use in paints for tinting or staining, they are very frequently referred to simply as *stainers*, or as *staining colours*.

The three main considerations as to quality which will probably weigh with the manufacturer in selecting samples of one or other of these pigments for paint making are—(1) the depth, richness and precise shade when the sample is ground by itself in oil; (2) the strength (staining power), with which must be included the quality of tint produced when the sample is reduced with a white base. This *low-strength tone*, if it may be so called, should be a characteristic one for each member of the group, as it is an essential property of a high-class staining pigment to yield after reduction with white a tint associated with that particular pigment, and one which no other pigment will produce; (3) the physical texture of the sample, which should be such that the particles, if not already finely powdered, will readily undergo disintegration during the grinding process. Those members of the group which have undergone a roasting process during their manufacture, *e.g.* burnt sienna and burnt umber, will be found to present great divergencies in this particular.

Considerable practical experience and a good eye for colour are necessary for dealing successfully with competitive samples of these pigments. It is of the greatest assistance to select and have ready for reference standard samples of

proved excellence, with which any doubtful or unknown samples may be compared. By making the comparison with the same standard at each trial concordant results will be obtained. If a true notion of the exact shade in oil of a given sample of a staining pigment be desired, it will not be sufficient merely to rub down the colour under examination with oil under the palette knife. The permanent and intrinsic shade which would be brought out were the pigment ground on the rollers is not always obtained by this means. If only a small sample is available, and hand-grinding is necessary, the operation must be conducted in a careful and thorough manner with a muller on a slab, nothing being more misleading than an imperfectly prepared hand-made sample. A good method of observing the tint is to place a small portion of the pigment previously ground in oil on a piece of glass, to add a drop of oil, and with the tip of the finger to rub out the mixture with a circular motion, gradually increasing the distance from the original spot of paint. In this way varying depths of colour are obtained, and an opinion can be formed as to its exact shade, brightness, and richness. When samples have to be reduced in order to determine their relative strength, the reduction should be considerable, say 1 part of pigment to 50 or even 100 parts of whitelead, and the comparison with the standard should be repeated using oxide of zinc as the reducing medium. The nature of the white-reducing pigment exerts no little influence on the final colour effect. The *low-strength tone*, characteristic of the different pigments, will be dealt with in connection with the various members of the group. A very good idea of the physical texture can be obtained by rubbing down a little of the dry powder under the muller on a slab, using rather more oil than for the other tests. Experience enables one to judge very accurately in this way as to whether the pigment will be easy or the reverse to grind on the large scale on the rollers.

Ochres.—Such ochres as belong to the group of staining

pigments are yellow in shade, and are obtained from the crude ochre by the mechanical processes of powdering, sifting and levigating. The colouring agent is essentially hydrated ferric oxide, and in general the natural ochres may be regarded as clays stained with varying proportions of this substance. By exposure to heat the hydrated oxide is decomposed, ferric oxide (Fe_2O_3) being ultimately produced, and a more or less red coloured pigment being obtained. Where the latter is of use in paint making it comes within the scope of the iron oxide pigments which will be dealt with in the next chapter. The proportion of ferric oxide (Fe_2O_3) found in the yellow staining ochres usually varies from 50 to 70 per cent. Such samples as contain this ingredient in the higher proportions are often of a less brilliant colour than those containing lower proportions of oxide; indeed, the line of demarcation between the ochres and the siennas is only an arbitrary one, and any strong-staining ochre containing a high percentage of ferric oxide, and of a somewhat dark yellow shade, may appropriately be called a sienna. The characteristic tone of the typical ochre should be a bright golden yellow. Ochres of this characteristic hue are increasingly difficult to obtain, and the difference in this respect between the so-called "grinding ochres" of to-day and those of twenty years ago is very striking. When reduced with a large excess of whitelead the pure yellow tone should be maintained. When a dry ochre is obtained which possesses this characteristic shade it is important that the paint manufacturer should assure himself that it is natural to the ochre, and is not due to the presence of *lead chrome*, which is often added in small quantity to the ochre in order to communicate to it the rich golden shade referred to above. Seeing that ochres are frequently employed in painting on account of their permanence, it is highly important that nothing that will prejudice this valuable property is admixed with them, either before or during grinding with oil.

Ochres may be conveniently classified, from the paint maker's point of view, according to their place of origin. Typical classes are—

(1) *English Ochres*.—When these can be procured possessing the characteristic shade, and free from extraneous tinting matter, they are unsurpassed in richness and strength of colour, but unfortunately good samples are now almost unobtainable.

(2) *French Ochres*.—Vast quantities of these are imported into this country in all qualities, the well-known trade names “J.C.” (*Jaune commun*), “J.F.L.S.” (*Jaune fin lavé surfin*), etc., indicating different grades of the class. Compared with the best English ochres, the French ochres are inclined to exhibit a somewhat bleached or dull appearance. The better qualities are remarkable for their fineness in texture, although here again there has been a marked falling off in recent years.

(3) *Italian Ochres*.—As a class these ochres approximate more nearly to the siennas in composition and shade than do the members of the previous groups. The best qualities are voluminous in texture, finely powdered, of a dark, rich colour, and possess considerable staining power.

(4) *Indian Ochres*.—Nearly every part of the world produces yellow ochre of some kind or another, but certain parts of southern Asia contain deposits of yellow ochre which possess very distinct merit. When freights are low it pays to convey these materials to Europe, but since the cost of carriage has been increased there has been a notable falling off in the imports.

Mixing and Grinding with Oil.—On account of their great absorptive capacity the ochres, in common with the clays in general, require a comparatively large proportion of oil to reduce them to a consistency suitable for paint, and as a rule the better the quality of the ochre the more oil will be required. A strong-staining and finely levigated Italian ochre may require very nearly its own weight of oil—the

proportion arrived at by actual experiment being for several high-class brands 87 per cent. This is a high figure, and indicates a pigment from which excess of silica and other impurities have been eliminated. For the ordinary grades of grinding ochre 25 to 40 per cent oil is the usual proportion required. Owing to the naturally sticky and adhesive texture of the ochres it is advisable to employ as the medium in grinding them one that will tend to counteract this feature as much as possible. Raw linseed oil possesses advantages on this account, and is also preferable to boiled oil in that it communicates no colour to the ground pigment, which boiled oil does, especially in the case of the paler and more delicately tinted ochres. It will be found that paint thinned out from paste-paint ground with boiled oil will usually dry several shades darker—a circumstance generally attributable to the driers contained in the oil. If raw oil is employed alone it is well to add from 2 to 4 per cent of moderately thick varnish foots during mixing. The selection of the medium will depend largely on whether the ground pigment is to be sold in paste form as a decorator's staining colour or is to be used in fairly large proportion in mixed paint or enamel. If the latter procedure is in view it is well to remember that ochre is one of the "bad drying pigments" and that the presence of a large quantity of raw linseed oil will tend to retard the drying of the paints.

The process of mixing must be thorough, and must not be hurried unduly. It will frequently be found that if sufficient time is not allowed for the oil and pigment to amalgamate and become thoroughly incorporated, the mixture, even when the usual proportion of oil is present, has a dry, crumbly appearance, and that if more oil is added to counteract this the paint is "sloppy" when ground. In many cases the correct consistency would have been arrived at by using the ordinary proportion of oil had the mixing been prolonged. It is important not to overstep the mark in the matter of oil, as, owing to the large proportion of oil

present, a small excess readily becomes apparent, and the efficiency of the grinding is greatly reduced. It is always advisable to allow the pigment and the grinding medium to remain in contact with each other for some time (twelve or twenty-four hours is not too long a time); before grinding in this way the medium soaks into the pigment and a more intimate mixture is obtained. The question arises—what type of mixing machinery most satisfactorily meets the requirements indicated above? It must be admitted that, in spite of the enormous strides that have been made in the construction of plant and machinery for paint-making, there is still a wide field for further improvement, and the keynote for such improvement is *specialization*. So far it has been the custom among makers of paint machinery (and this refers particularly to mixing machinery) to represent a particular machine as being suitable for every kind of paint. But the practical man will on reflection find that each class of paints has its own peculiarities and its own requirements, and consequently a mixing mill to suit all classes will have to be a mass of compromises—and compromises in machinery are seldom entirely satisfactory. The truth appears to be that special requirements in the way of paint-mixing machinery have been somewhat overlooked by the makers of paint plant. It is certain, however, that the paint manufacturer who aspires to success through economical handling of his raw materials and excellence in his finished product will have to bestow no little attention to his mixing machinery, and to consider each class of pigment on its own merits. Regarded in this light, the ochres present difficulties in the mixing process that few of the usual forms of mixing machinery entirely overcome. If intelligent handling on the part of the workman can be depended on, very satisfactory results can be obtained by the use of the type represented in Fig. 9 (see p. 38). After being mixed in such a mill no ordinary ochre paint should require more than two grindings on the usual form of granite-roller mill

provided the stiff paint is to be used as a painter's staining colour. In the case of material intended for use in enamels and highly finished articles of this class four, five or more grindings may be necessary, and even then the last trace of grit can often be removed only by grinding through a steel-roller mill. The grinding process, if the mixing has been correctly performed, and the proportion of oil carefully adjusted, will present no difficulties. As already stated, the stones will "bite" better, and finer grinding will result if a thin instead of a viscous oil is used; on the other hand the medium should possess siccative properties. Great care should be taken to ensure that the dry colour is dry. If the ochre is mixed damp it will grind out in flakes. An inexperienced or careless workman will probably add more oil to counteract this tendency, with the result that after the paint has lain for some time the excess of oil will separate out, leaving the colour in an unworkable state. Excess of silica in the ochre (indicating insufficient levigation) will also cause the oil to separate. Of all the causes of defective results in ochre paints the most common is silica.

Siennas.—Natural sienna earth, which takes its name from Sienna in Tuscany, has a composition closely related to that of the ochres, and in particular to that of the Italian ochre already referred to. According to one hypothesis, the deposits of ferruginous earth from which the siennas of commerce are derived have been formed by alluvial clay becoming impregnated with chalybeate waters (waters containing soluble salts of iron). The presence of organic particles (which may have been bacteria) has caused decomposition of the solution of iron, and particles of hydrated oxide of iron have been precipitated.

The colour of raw sienna of good quality varies from a somewhat orange-tinted yellow to a dark, dull yellow, with a tinge of green. It is in water-colour and fresco work that the true natural sienna tone is in chief demand, and it is principally in interior decoration that this pigment finds a

use as a stainer. Raw sienna possessing the characteristic hue associated with this pigment is none too common, and some discrimination is necessary in purchasing it.

By calcining raw sienna there is obtained burnt sienna, one of the most widely used and characteristic of the staining colours. The shade of burnt sienna varies to some extent, but it should always be a rich, lively and transparent brown-red. When reduced in a large excess of whitelead this pigment should yield a warm yellowish tone, and not a cold pink. The latter indicates either a poor quality of sienna or bad manipulation in the burning. The size and hardness of the particles should be tested by the buyer, as a hard and gritty burnt sienna will often be found to lack brilliancy, besides being difficult to grind.

It is a matter of practical difficulty to secure absolute uniformity in shade from different burnings of even the same raw sienna; much more is there a likelihood of variation when different parcels of raw siennas are calcined. Paint manufacturers who use large quantities of this article would therefore be well advised in making a careful selection of three or four good qualities, and in blending them for grinding. In this way a slight variation in one or other of them would not affect the bulk to a serious extent.

In the matter of the quantity of oil used in grinding, the precautions which should be taken during the process, and the choice of mixing machinery, the remarks already made with reference to the ochres apply in general to the siennas also. Burnt sienna, however, as might be expected from its mode of preparation, works during mixing in a manner intermediate between the clay-like ochres and the oxide colours—that is to say, it is less crisp and sticky than the former, and a more viscous oil may be used without prejudice to efficient grinding. Three parts of raw and one of boiled linseed oil, with 2 to 4 per cent of stout varnish foots, will, as a rule, be found a satisfactory mixture for use with a pure burnt sienna of good quality. With raw

sienna, as in the case of the ochres, the oil should be raw linseed. When circumstances permit, it is an excellent plan to let the pigment remain in contact with the grinding-medium for six to twelve hours before grinding. More thorough absorption is then secured, and grinding will be easier and more effective. This remark applies to all pigments requiring large proportions of oil, such as the ochres, siennas, umbers, Vandyke brown and the like.

Effective grinding of the more refractory of the earth staining colours, of which burnt sienna and burnt umber are typical, will only be obtained by heavy and prolonged pressure. The old-fashioned flat, or table, stones were pre-eminently adapted for this sort of work, but their small output has practically put an end to their use.

The remarks on grinding under the heading of *ochres* apply to siennas also. A first-rate grade of burnt sienna may require as much as 104 per cent of oil to grind it to a stiff paste. Lower grades require from 85 to 95 per cent. The best and most voluminous varieties of raw sienna require even larger proportions of oil, as much as 128 per cent being not uncommon, although the percentage may be as low as 90 in the case of ordinary grades.

Umbers.—The composition of these substances is somewhat more complex than that of the members of the preceding groups of earth pigments, and has given rise to some controversy among chemists. Typical samples of umber may be considered as consisting of ferric oxide (Fe_2O_3), 40 to 50 per cent; manganese di-oxide (partly as MnO_2 and partly as Mn_3O_4 , but calculated as MnO_2), 15 to 20 per cent; organic matter, 8 to 10 per cent; these components being associated with variable proportions of silica, alumina, etc. In the native umber the iron and manganese are present in the form of hydrated oxides, which are of course decomposed when the pigment is calcined in the preparation of burnt umber. In general, the presence of considerable proportions of manganese and organic matter, and the

absence of large proportions of alumina, are characteristics common to the umbers. The finer qualities of umber, obtained from various parts of Southern Europe, are usually referred to as Turkey umber; the varieties mined in England are of less value to the paint-grinder, and possess in a much less degree the characteristics of the typical umber.

Raw Turkey umber appears, after the usual dry grinding, levigating and drying in the form of a voluminous brown pigment, yielding, on reduction, yellowish-brown tones. When calcined it becomes *burnt umber*, and assumes a redder shade, while on reduction with whitelead or oxide of zinc it yields warm brown tones.

Owing to the absence of any large proportion of alumina, and owing to the presence of silica, umber paint presents a different appearance during mixing and grinding to either ochre or sienna paint, being softer and lacking crispness. The latter property can be communicated by adding a proportion, say 5 to 10 per cent, of china clay, but the opacity of this substance being considerable, it should be borne in mind that the staining power of the paint will suffer somewhat in consequence. The remarks made under the heading of sienna in regard to oil will apply to umber as well, but the proportion required will vary greatly. High-class burnt Turkey umber requires about 85 per cent of its weight of oil, while a good grade of raw Turkey umber takes 66 per cent.

Owing to the powdery nature of the umbers the process of mixing with oil must be conducted carefully, and batches should never be left in a half-mixed condition otherwise heating and burning are liable to occur. The same type of machinery may be used as in the case of ochres and siennas. UMBER is usually spoken of as a drying pigment, nevertheless some curious features are met with when it constitutes the preponderating pigmentary base in a paint. Special mediums must be designed if good drying properties and maintenance of gloss are to be looked for.

Vandyke brown.—The pigment so largely used by Vandyke was an earth from the neighbourhood of Cassel. The modern substitutes are of variable composition, and are prepared with a view to imitating the old master's colour. Probably the best definition of the modern pigment used in paint grinding is—a carbonaceous or bituminous ochre or frit containing manganese, possessing a certain amount of transparency, and yet enough opacity to act as a body colour. Ground in water it is largely used as a tinting medium, and yields on reduction rather cold grey-brown tones. Vandyke brown is not, even when pure, a very strong staining colour, as compared with those staining pigments already referred to. In valuing samples of this pigment regard must be paid to its richness and shade when undiluted, as well as to the staining power. Vandyke brown of the composition indicated reacts when boiled with carbonate of soda or other alkali, and a compound results which is soluble in water, and which is used as a water stain. Many so-called Vandyke browns, however, are merely lamp black tinted with brown or red oxides of iron, and these must be looked upon as imitations. Natural Vandyke brown is the least permanent of the members of the class now under discussion. Yellow ochre and the siennas may be regarded as practically unalterable, even after exposure to moist air; umber shows signs of alteration under the same conditions, and Vandyke brown is distinctly altered.

The mixing and grinding of Vandyke brown with oil presents a good many practical difficulties, and owing to the very varied composition of the pigment it is difficult to formulate general rules which will apply in every case. It is one of the lightest pigments the paint-grinder has to deal with, and a large proportion of oil is necessary in grinding it, 100 per cent on the weight of dry pigment being quite a usual proportion. The oil is with difficulty absorbed by the pigment, and after being ground into the latter very readily separates out again. It is therefore de-

sirable to let the oil and pigment remain in contact over night before the systematic mixing takes place; this procedure also prevents particles of the dry colour escaping during mixing, should this operation be conducted in a pan-mill. With Vandyke brown of good quality the mixture of oil and pigment before grinding will be quite thin, but after grinding it will stiffen to a jelly-like consistency, which is the nearest approach to a paste that is possible with this pigment. The finished paint should be looked at a day after it has been ground, in order to see that it is in a saleable condition, as it is sometimes found that the proper consistency is not maintained, but that the mixture assumes almost a liquid appearance. The use of boiled linseed oil and a proportion of varnish or varnish foots will not be found to do much towards rectifying this tendency.

If the paint is to be used merely as a body colour a vastly better result will be obtained by using 25 to 50 per cent on the weight of pigment of terra-alba, and in this case a trace of vegetable black and (if desired) of chocolate oxide may be added to correct the shade. Vandyke brown is not held in repute as an ingredient of mixed paint or enamel on account of its poor drying properties. Indeed it actually retards the drying of linseed oil and furthermore it not infrequently exerts curious effects on varnish applied over paints containing considerable proportions of the pigment.

CHAPTER VII.

THE GRINDING OF OXIDE OF IRON PIGMENTS.

OF all coloured pigments, oxide of iron probably holds the premier position in paint-grinding. Very large quantities are used as the basis of mixed paints under such names as Indian red, Turkey red, Venetian red, purple brown, red oxide, Persian Gulf ore, and others. No pigment lends itself to adulteration and sophistication more readily, and consequently the cheaper classes of paint made from oxide of iron (many of them known by high-sounding titles such as "metallic paint" and "anti-corrosive paint" have become a by-word.

The term *oxide of iron*, used in its widest sense, includes the various hydrated and anhydrous oxides of the metal that form the basis of the ochres, siennas, and iron reds and purple oxides of commerce. In this chapter we shall deal only with those pigments which the practical paint grinder usually classes together as *oxide colours*, the yellow ochres and siennas (which are usually grouped under the heading of *staining colours*) having been dealt with in the preceding chapter.

Red is the prevailing colour of the pigments now under consideration, but this may vary in shade from nearly yellow to dark purple or nearly black. The reason for the popularity of iron oxides in paint making is not far to seek. They are in the first place very permanent. Outside influences, of which the chief are oxygen and moisture, have no effect on them, and they are as a rule inert when in contact with other pigments. Further they possess as a class great tinting power, and in many cases (though this is

by no means universal) considerable opacity. Finally they are not costly, and the operations connected with their manufacture are for the most part simple.

As paints made from this group of pigments are employed chiefly as self-colours, and not as staining or tinting pigments, it is essential that they should possess great opacity. It is well to remember that a high staining or tinting power in the dry pigment does not by any means ensure that the opacity is proportionately great. Great staining power is not infrequently sought for by the paint manufacturer in order that the paint may be more largely adulterated without detriment to the shade of the paint. Another noteworthy point is that neither the opacity nor the tinting power is always or uniformly proportional to the percentage of ferric oxide in the pigment. Thus certain purple oxides containing as much as 90 per cent of ferric oxide are very poor stainers, and in opacity do not rise above mediocrity.

Detailed information in regard to the manufacture and the composition of the various oxide of iron pigments which are offered to the paint-grinder does not come within the scope of the present volume. Nevertheless the following general classification may be found useful, and the practical points which will be noted in connection with it may be of some value in determining the utility or otherwise for paint-making of a particular sample of pigment.

(1) **Reds.**—Under this heading may be grouped the very numerous pigments which possess as their leading characteristic a more or less pronounced pure scarlet colour. Natural red oxide, burnt red ochre, the so-called Venetian and Turkey reds, scarlet oxides and copperas reds are typical members of this group. Only such as are comparatively rich in ferric oxide (Fe_2O_3) are useful as paint bases. Although as already stated a high percentage of ferric oxide is not in itself a criterion of the paint-making qualities of the dry colour, yet it is advisable where practicable to buy

the pigment on a guaranteed percentage of this component, attention being also paid to the paint-forming properties of the sample under examination. Further, it is well for the paint manufacturer to know what other ingredients besides ferric oxide the pigment contains. Take, for example, the case of a red oxide containing 80 per cent of ferric oxide (Fe_2O_3). What do the remaining 20 parts consist of? It may be (according to the origin and method of manufacture) chiefly silica, or alumina, or gypsum, or whiting, or a mixture of two or more of these, and the resulting paint will vary in texture, in opacity and in staining power, in proportion as one or other of these components preponderates. A high percentage of silica will result in the paint preserving its staining properties, but falling short in opacity. The presence of whiting will act in a precisely opposite manner. Alumina (present in the form of silicate of alumina or clay) has in moderation a beneficial effect, causing the paint to have a certain crispness. For this reason china clay is sometimes added in small quantity to paints that would otherwise lack this setting-up tendency. Nevertheless this ingredient must be added with caution, otherwise its opacity, which is considerable, will react on the brilliancy of the paint.

The colour of the better-class members of this group should be when the pigment is ground in oil a pure, brilliant scarlet; no purple or brown tint should be apparent. When reduced with a large excess of whitelead or other white base warm terra-cotta tones are obtained.

As a class, these reds are remarkable for their permanence, and for their opacity and obscuring properties when made into paint.

(2) **Purples.**—These too form a very large and important group of oxide pigments. The gradations of shade are practically infinite. On the one hand, they merge by imperceptible degrees into the true reds already referred to, and on the other into the deep blue-black pigments known

as *deep purple browns* including between these extremes the numerous so-called *middle purples*, as well as a great number of pigments of a purplish-red, chocolate, or brown appearance. Here, as in the former class, the aim should be to select pigments that give pure and characteristic shades. Thus a light purple should be of a rich crimson tone, a deep purple should have a pure plum-colour shade, while a middle purple should be intermediate between these. The common property, however, is that all, when rubbed out with a large excess of whitelead, yield cold blue tones; in this respect they differ from the siennas. A pure brown or chocolate colour may be desired for certain ironwork paints. Here again purity of tone should be sought for, and an oxide selected which will produce a shade as near that of burnt sienna as possible. The point which it is desired to emphasize is that, if a few pure shades are chosen and stocked, very slight tinting by means of carbon black, Prussian blue, sienna, umber, or a suitable pigment lake will suffice to produce practically any of the variations which the paint grinder is likely to be called upon to offer.

It is a matter of common knowledge among practical paint-grinders that the deeper shades of purple oxides are somewhat unsatisfactory in their behaviour on grinding. The particles of the dry material are often exceedingly granular in texture, and unless grinding is conducted in a careful manner this effect is sure to reappear in the ground colour. There is often a difficulty in getting the oil and pigment to incorporate one with the other permanently, which results in the paste-paint, after lying some little time, assuming that sloppy incoherent texture so characteristic of faulty manipulation. When the staining power of the pigment in use allows of it (and it must be borne in mind that the deep shades of purple brown are not, as a rule, remarkable for their tinctorial properties), it will be distinctly to the advantage of the paint to add a proportion of whiting, the paint thereby gaining considerably in opacity. If then

raw linseed oil be used for mixing, or 2 parts of raw to 1 of boiled, and 3 to 5 per cent on the total weight of colour *plus* oil of good stout varnish added, the resulting paint will be found to bind well together and to retain its consistency on keeping.

Attention has already been drawn to the somewhat feeble staining properties of the deep-shade purple oxides. A natural result of this weakness is that the lower priced deep-purple oxides have frequently a decided brown or chocolate appearance, proportions of strong-staining oxides of the latter class having been added to the dry pigment to mask the lightening in colour due to the addition of gypsum, whiting, or barytes. An artificial blueness is also obtained by the addition of a small trace of Prussian or celestial blue to the oxide. It need hardly be mentioned that, so far as paint grinding is concerned, such tinting, if necessary at all, is much better done by the paint manufacturer himself.

Chocolate-coloured oxides have been referred to under the heading of purples for the sake of convenience in grouping. Some pigments of this shade are met with which are so characteristic that they might well be grouped separately. Notice may be taken, for instance, of certain natural oxides rich in ferric oxide, and possessed of a pure warm-brown shade, almost approaching burnt sienna in richness. Among those who have given some attention to the subject, oxides of this class are highly valued for their permanence and for their tendency, when made into paint, to adhere closely to the surface to which the paint is applied. The brown colour of iron rust is familiar to every one. This rust, formed slowly and spontaneously by the action of atmospheric air and moisture on iron, is molecularly and chemically the most stable form of ferric oxide—the ultimate product of slow oxidation. Oxides of precisely similar chemical composition are met which possess a bright-red colour, but it is a well-recognized doctrine of colour technology that brightness is associated with instability—if not chemical, then molecular

or physical. The rusting of iron has been shown by various investigators to be promoted not by chemical agencies alone, but to be in many cases intimately associated with electrolytic action. In what manner and how far this action is connected with the chemical composition of the pigments and with such physical properties as colour, size of particles, etc., it would be premature at present to surmise. Even those who have devoted much time and labour to researches on the subject are not agreed. So far as the paint-grinder and the paint-user are concerned, the important fact is that carefully selected chocolate-red or brown oxides are probably the most stable of any. One point may be noted in this connection. It is that films of paint containing oxide of iron appear to be somewhat permeable by moisture and gases. Hence some authorities consider them unsuitable as protective coats to resist atmospheric influences. There is no doubt, however, that this tendency can be greatly minimized by suitable adaptation of the grinding and mixing mediums.

Indian red is, with the exception of some of the higher-priced bright Turkey reds, probably the most highly finished oxide that finds its way into the purchaser's hands. It contains a very high proportion of ferric oxide, often well over 90 per cent.; it has been dry-ground with care and has been thoroughly floated, so that there is an entire absence of grit; and finally, the colour is a deep red—not purple and not brown—though this varies within limits, there being light Indian red and deep Indian red. As this article is usually required for high-class decorative work, where price is not so much a consideration as first-rate quality, it behoves the paint manufacturer to pay particular attention to it and to pigments of similar grade.

Briefly summarizing the foregoing, therefore, we see that in the bright or Turkey reds, in the various shades of purple oxide, in the chocolate-coloured oxides, and in Indian or dark reds, are presented the typical shades of oxide of iron in its pigmentary form. It is to the paint-grinder's interest

to see especially to the following points when estimating the probable value of one or other of these pigments for paint-making—(1) The origin of the dry colour should be known to him, i.e. whether it is a native oxide or a calcined earth or ochre, or a chemically prepared oxide. The latter class includes oxides obtained as by-products from spent iron liquors, and also the so-called *copperas reds*. None of these can be thoroughly relied upon for permanence *under all conditions*. The words in italics are of importance, because under certain conditions a good strong-staining copperas red may be the most suitable and economical colouring matter for the paint-grinder to use. But if the oxide has to be ground alone in oil, and the paint is to be applied to ironwork, then the advice offered is—Do not use any chemically prepared oxide. A natural oxide of suitable colour, which has undergone no treatment but dry grinding and efficient levigation, will be found in such cases the safest to use. The reason for this advice is the well nigh universal presence of free acid or acid salts in such pigments. When oxide of iron pigments are intended for use in artists' colours it is usual to subject them to a process of boiling and washing in order to get rid of traces of acid. (2) The most minute trace of free acid in an oxide intended for paint-making is to be deprecated, especially if the paint is to be used on ironwork. The improvement during recent years in dry-grinding machinery has enabled oxide manufacturers to offer for paint-grinding numerous finely powdered pigments, which would in years gone by have had to undergo a washing process as well. The great advantage of the floating process was to eliminate siliceous particles; for silica, as has been already stated, has an influence on the paint the reverse of beneficial.

There is a small, but not uninteresting, class of oxide of iron pigments used in the fabrication of paint, whose pigment-base is the less highly oxidised compound usually referred to as *magnetic oxide of iron*, which corresponds to the formula Fe_3O_4 . These oxides are for the most part offered to the

paint manufacturer as reddish-brown, chocolate-coloured, or nearly black powders, containing from 70 to 90 per cent of ferroso-ferric oxide (Fe_3O_4). They are readily distinguished from oxides of the ferric class by the property they possess of being attracted by the magnet. It was the fashion some years ago to ascribe to oxides of this class very special preservative properties when they were employed as protective coatings for ironwork. This conclusion was probably not arrived at by carefully verified practical tests, but was more probably the result of a process of reasoning by analogy. No better protecting coat for iron is known than the thin film of black magnetic-oxide formed by the exposure of red-hot iron plates to a current of steam. But the painting of an iron surface, the pores of which are already saturated with oxygen and moisture, with paint composed of ground magnetic-oxide is by no means an analogous process; hence it is open to doubt whether this class of oxide possesses preservative properties superior to those of the ferric class already referred to.

The red and brown-coloured members of the group possess considerable opacity and moderate staining power; the so-called black shades, on the other hand, are notably deficient in both these properties.

Mixing the Dry Pigment with Oil.—This process should not be conducted in a haphazard manner, but should be carefully performed, as the subsequent grinding is influenced by the preliminary mixing. A mixer of the horizontal type (see Fig. 25 p. 51) is often used for this purpose. It is preferred by some to the vertical pug-mill for mixing oxide paints, on account of more efficient mixing being possible in a shorter space of time, with less attention on the part of the workman. If the proportions of oil and pigment have been previously worked out from a trial mixing, all that the mash-maker requires to do is to weigh accurately the succeeding charges; the mill, if it is suitably constructed, can be trusted to do the rest. With the vertical type of mixer, on the other hand,

constant attention is necessary in charging, otherwise owing to the lack of resistance in paint of this variety, the knives are liable to cut through the mixture of pigment and medium without stirring the whole mass.

Either raw or boiled linseed oil or a mixture of these may be used in the mixing of oxide of iron pigment paints. Owing to the non-drying nature of oxide of iron, and also to the fact that a relatively large proportion of oil is required in grinding it, the use of boiled linseed oil or of some suitably compounded medium possessing siccative properties is on the whole preferable. It is very important, if really excellent paint is aimed at, that the oil should be of good quality, and free from rosin and an excess of driers. The presence of these ingredients will injure the wearing properties of the mixed paint, and will cause it to perish sooner than it should do. Whether raw or boiled oil is used, it is well to add a small proportion of good varnish foots, in order to prevent the stiff paint turning soft and sloppy on keeping. If raw oil is used the proportion of varnish foots may be increased to about 4 per cent of the total mixing.

The quantity of oil required varies with different oxides, but 18 to 22 per cent (on the weight of the dry pigment) are usual proportions. In every case when a new parcel of pigment is being dealt with, the best plan is to make a trial mixing with carefully weighed quantities, and to grind this and put it aside for twenty-four hours. When the correct consistency is thus arrived at, perfect uniformity in the successive charges should be insisted on, because a little extra pugging may cause a temporary slackening, which is apt to be misleading if the cause is not known.

Oxide paints are usually considered to require double grinding. This is necessary not only to ensure the removal of all grit, but also to ensure maximum opacity and spreading power in the finished paint. Fineness of the particles also increases the protective properties of the paint. In order to reduce handling as much as possible, it is advisable, when

practicable, to arrange so that the mixed pigment and oil, after falling from the mixer on to the first set of rollers, shall feed from the latter on to the second set. The drawback which in former days was associated with this method was that the upper set of rollers was not under the immediate control of the grinder, and there were also structural objections to having rollers off the ground level. These disadvantages have been obviated in the newer types of plant.

Owing to the nature of oxide of iron paint of average quality comparatively large quantities can be ground in a given time. When properly handled, a 30×15 triple granite-roller mill ought to turn out from 35 cwt. to 2 tons a day of twice-ground paste-paint. The wear and tear on rollers which have to grind large quantities of this material will be found to be considerable, and will probably manifest itself in numerous grooves running round the stones. Wearing of this nature will become apparent sooner when it is attempted to turn out the paint with only one grinding, it being necessary in this case to screw the rollers more tightly together. Grooving of the rollers is much lessened, if not entirely obviated, by having a lateral motion on the centre roller. This movement should be a slow and steady one. A further advantage will be gained by arranging that the first grinding shall be more or less of a preliminary one, and that the full pressure is brought to bear during the second grinding. By the observance of these precautions the life of the rollers, which is liable to be materially shortened when refractory substances like those now under discussion have to be dealt with, will be lengthened.

A passing reference must be made to that very large class of paints composed of oxide of iron reduced with varying proportions of natural barytes, whiting, or gypsum. In these the general character of the particular paint depends on the nature of the preponderating ingredient, and the oxide of iron may be considered as simply a tinting medium. Hence for such purposes oxide pigments will be chosen

which possess great staining power. So long as the proportion of oxide is sufficient to prevent undue poverty of shade, and the mediums used in the mixing are properly designed, reduced paints of this kind will be found to yield a fair measure of satisfaction, although the same permanence and general excellence cannot be looked for as in the case of the undiluted oxides.

Engineers' specifications for oxide of iron paint frequently specify that the dry powder shall contain a given percentage of ferric oxide (Fe_2O_3). Should the manufacturer be at liberty to use an oxide containing a higher percentage of real ferric oxide, and to reduce it to the required strength, the following formula will give the number of parts of cheapening material that will have to be added to 100 parts of the stronger oxide to bring it to the required strength:—

$$x = 100 \frac{p - p'}{p'},$$

where p is the percentage of ferric oxide in the stronger oxide, and p' is the required percentage. Thus, if 80 is the percentage required, and 98 is the actual percentage of oxide in the dry powder to be used, then the number of pounds of adulterant that may be added to every 100 lb. of the strong oxide will be

$$100 \times \frac{98 - 80}{80} = 22.5 \text{ lb.}$$

Where the cheapening agent is itself an oxide containing y per cent of real ferric oxide, the equation will read

$$x = 100 \frac{p - p'}{p' - y}.$$

Thus if $y = 50$, and p and p' represent the same values as before, it will be found that 60 lb. of an oxide of 50 per cent strength must be added to 100 lb. of an oxide of 98 per cent strength to yield a powder containing 80 per cent of real ferric oxide.

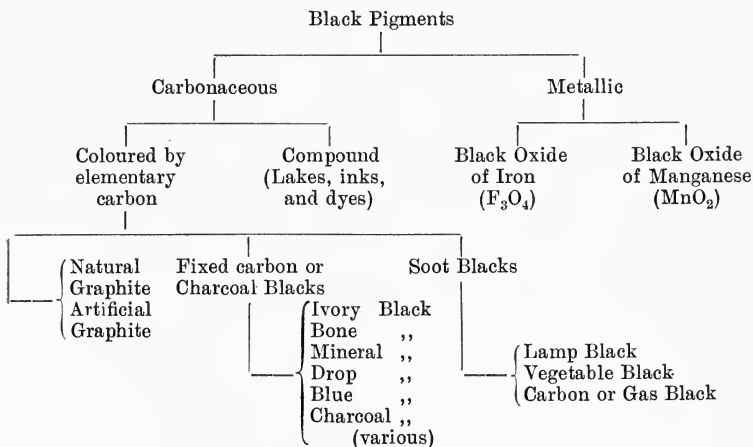
The same formulæ may be applied in calculations relating to the reduction of other materials to a given percentage composition, as for example barytes or other diluent in reduced whitelead.

CHAPTER VIII.

THE GRINDING OF BLACK PIGMENTS.

CARBON in one or other of its numerous forms is the colouring agent in practically the whole of the black paints of commerce. Two pigmentary substances of metallic origin are used to a limited extent, and therefore deserve mention. They are the di-oxide of manganese (MnO_2) and the magnetic oxide of iron (Fe_3O_4) which has already been referred to in the section devoted to the oxide colours. The use of these two pigments is limited almost entirely to cases where carbon would be inadmissible, e.g. in the making of coloured tiles; for the paint-grinder consequently they possess only a limited interest.

CLASSIFICATION OF BLACK PIGMENTS.



Owing to the numerous varieties of carbon or of carbonaceous matter which are useful to the paint-grinder as tinting media, the classification of these substances in a rational

manner is somewhat difficult. Malepeyre and other writers since his classic work was compiled, adopt a classification based on the origin of the black pigments from animal, vegetable and mineral sources respectively. The introduction of new forms of carbon has rendered such a classification at the best incomplete. In the present instance it has appeared best to follow a system based upon the method of production, as well as the origin, of the various blacks mentioned.

If we eliminate graphite, which we will discuss later, we may consider black carbonaceous pigments as belonging to one or other of two great classes—(1) charcoal or fixed carbon blacks, (2) soot blacks. In the first of these groups the pigment consists of a carbonaceous mass or residue in which the carbon, to whose presence the tinctorial properties of the pigment are due, is “fixed” by an incipient coking process. The general mode of preparation of the members of this group consists in the carbonization of suitable raw material in closed vessels with a limited supply of air, and the term “fixed” appears to be a convenient description to apply to the members of the class. It indicates that the pigmentary carbonaceous product is produced and is retained within the combustion chamber. Thus are produced the so-called mineral blacks which result from the carbonizing of bituminous schists in closed retorts. By treating Scotch boghead mineral in this way a charred mass has been obtained containing 30 to 40 per cent of carbon. Mineral black or powdered coke of this nature, and of varying value in regard to carbon, is a common ingredient of the cheaper black paints. Although its tinting power is small its preservative properties are considerable, and along with white-lead in slate colours and greys it can be recommended.

An important sub-class of the fixed blacks consists of the ivory and bone blacks. At the present time ivory black differs from bone black only in the quality of the bones used, the finest and most ivory-like being used for the finer grades

of bone black, which are sold under the name of *ivory black*, a term which nowadays means but little, as black obtained from true ivory is a commercial rarity. The "drop black" and "drop ivory black" usually met with in the trade are really bone black. In the preparation of bone black the bones are distilled and are finally partially coked. The charred remains are extensively used in sugar refining, and it is after the black has done duty in this way that it is usually placed in the paint manufacturer's hands. The colour of bone black varies very much, the quality of the bones, the temperature of the charring, and the subsequent treatment all influencing the result. As it is one of the most important of the black pigments, the paint-grinder cannot be too careful in his examination of it. Ground in oil it forms a very dense, brilliant black, and is a trustworthy ingredient of the ordinary black paints which are likely to be used as self-colours. In staining power it cannot compare with carbon or gas black, consequently if the grinder desires to prepare a paint which is to be used for staining or tinting purposes it will not, as a rule, be found economical to use bone black entirely. Owing to its well-known action on organic substances, caution should be observed in blending it with pigments of organic origin. The proportion of carbon contained in bone black of good quality varies from 12 per cent upwards.

In the second class of pigmentary blacks, the various members composing it are produced by condensation of the particles of unburnt carbon outside the combustion chamber, whence the general term "soot blacks" may be appropriately applied to them. The leading member of the group is *lamp black*, the main source of which is waste oil and grease, and, in particular, the "dead oils" obtained in the distillation of coal-tar. The smoke and soot produced by the partial burning of such substances when collected by suitable means yield the ordinary lamp black of commerce, and the quality of the latter will vary with the materials

used and with the exact conditions under which the burning is conducted. The finest grades of lamp black (which are also those condensed farthest from the furnace) are termed *vegetable blacks*, a term which had its origin at a time when the finer seed oils were used to produce the article.

Lamp and vegetable blacks contain from 80 to 95 per cent of carbon, and their staining power is directly proportional to the percentage of this ingredient. Lamp black that has been condensed close to the furnaces will often be found to contain considerable proportions of tarry matter and of naphthalene, which diminish its value for paint. These incidental ingredients may readily be tested for by heating a little of the dry black in a dry test-tube. These substances will, if present, volatilize, and will recondense on a cool part of the tube. Adulteration of lamp black is frequent, black oxide of iron and cheap mineral black being both found as adulterants. As the staining power of both these articles is much inferior to that of even moderately good lamp black their presence is not to be desired.

The utilization during recent years of the volatile hydrocarbons which escape in the neighbourhood of the American oil wells has brought into the market a variety of carbon of a high degree of purity, and which is excellently suited to act as a tinting medium in black paints. This *carbon* or *gas black* was originally produced by condensing the products of combustion of the natural gases, but there is reason to believe that materials produced by the combustion of oils are now included in the description carbon black. It is probably the purest carbon pigment known. Its staining power is very great, but owing to its granular texture a considerable amount of grinding is necessary in order to obtain the maximum staining power. It is usually the favourite black for staining barytes or whiting to the depth of colour necessary to enable them to pass muster as black paints.

Wood charcoal black, cork black and vine black are

varieties which now possess a more or less historical interest only.

No list of carbonaceous substances capable of being used as pigments would be complete without a reference to *graphite*. Although this substance possesses properties which give it a certain value for paint-making, the difficulty experienced in getting it to incorporate permanently with a liquid medium prevented its use extending in the first instance when it was introduced.

Technical research has overcome these difficulties and at the present time graphite enjoys a fairly wide use as the pigmentary base of protective paint for iron and steel. It comes on to the market in two distinct forms, natural graphite which possesses a grey silvery appearance and is slippery to the touch, and artificial graphite which is blacker and denser and more amorphous in character. Great care and considerable technical experience are necessary in selecting graphite for paint-making inasmuch as there are enormous differences in the texture and quality of different samples, and the price varies from 12s. to more than double that figure per cwt. After a suitable grade of graphite or a mixture of different grades has been selected the key to success will be found in the selection of a suitable medium. As only 3 to 6 lb. of graphite are contained in a gallon of the prepared paint it is best to grind the pigment in the medium with which it will be thinned for use. Graphite paints should contain little or no volatile spirit.

Turning now to some considerations connected with the employment of the usual varieties of black pigment in the making of paint, the first question to be decided is—For what purpose will the paint be used? As alternative uses, we may mention (1) decorative work, which requires a full-bodied jet black capable of being used chiefly as a self-colour; (2) tinting or staining, which requires a finely ground and very strong paint of a composition suitable for the production of pure grey, slate-coloured, or lead-coloured tones; (3)

protection of wood, iron, or stone, or as a leading ingredient in paints to be used as protective coverings on one or other of these surfaces.

If a decorative paint pure and simple is required, the basis may be bone black, which combines good opacity and colour with the property of incorporating well with the oil; carbon black may be added to increase the depth of colour, and, as a somewhat blue tone is usually associated (somewhat erroneously perhaps) with a true black, a trace of Prussian blue may, if desired, be added. Unfortunately, buyers of paint will seldom pay the price of an unadulterated black of this description, and cheapening agents have to be introduced. Of these, barytes and whiting, in the proportion of two parts of the former to one of the latter, are likely to be selected; and so long as their use is not pushed to extreme limits, the paint can still be prepared of a quality suitable for this particular purpose. In a reduced paint of this nature, however, it is not a bad plan to include a proportion of good lamp black, say from 7 to 14 lb. per 112 lb. of total dry ingredients. Boiled linseed oil or a specially prepared siccative grinding medium should be used in the grinding of these paints, and the addition of a proportion of varnish, or good varnish foots, will much improve the paint not only in mechanical texture, but in durability.

Black paints of the second class—those, namely, to be used as tinting or staining colours—must of necessity be prepared from the strongest black pigments obtainable. The only pigments suitable for this purpose are lamp or vegetable black and carbon black. If mere strength were the only point to be considered, then carbon black would take first place, but in preparing a tinting black we have to remember that the shade produced by small additions of the tinting colour to a white base will vary according to the black pigment used in the paint. Thus carbon black will produce a brown-grey and vegetable black a blue-grey tone, while the shade obtained from lamp black will vary some-

what, but will possess in most cases the characteristics, though in a reduced degree, of vegetable black. Again, carbon black presents difficulties in grinding which the lamp blacks as a class are free from.

Where a really superior black paint for tinting is wanted, vegetable black of good colour may be taken as a base, and from 10 to 25 per cent of carbon black may be added, the grinding being conducted with boiled oil and varnish as before ; or lamp black may be substituted for the vegetable black, with of course a corresponding loss in staining power in the resulting paint.

Both vegetable and carbon blacks absorb considerably more than their own weight of oil in grinding ; mineral and bone blacks take much less, but the exact quantity varies greatly with different samples.

As protective coatings black paints, with the exception of the graphite paint already referred to, are only employed in special circumstances. It is generally conceded that carbon as a protective covering is less suitable on iron or steel than on wood. Indeed there may be positive objections to its use as a protection for metallic surfaces. A carbonaceous deposit on iron or steel tends to assist corrosion by acting as a nucleus to retain moisture and acids. It also induces electrolytic action, carbon being electro-negative to iron. This statement is no doubt less applicable to a well-finished paint containing a suitably adjusted medium and probably a proportion of basic pigment such as lead oxide, than to the roughly prepared mixture of lamp black and oil which is not infrequently applied to ironwork as a priming coat. In such matters wide generalizations are unsafe and misleading.

On a wood surface the case is entirely different, and a priming coat composed of or containing lamp black will give good results. A priming coat of lead paint which contains carbon will, as a rule, last better than one composed of whitelead only. Experience has shown that one

of the best methods of preserving wood posts which are to be sunk in the ground consists in charring the surface, which practically means interposing an absorptive and porous layer of carbon between the soil and the wood.

The valuation of samples of black carbonaceous pigments for paint-grinding resolves itself into the determination of two properties—colour and staining power. The buyer should assure himself that a rich deep shade in oil is not the result of artificial blueing. Since the staining power depends on the proportion of real carbon present, it is always advisable to determine accurately the percentage of this component, and an examination of the ash (if any) will give much information as to the probable origin and mode of preparation of the pigment.

Grinding in oil.—Owing to the exceedingly fine state of division of the particles of the finer varieties of carbonaceous blacks, and to the large quantity of oil necessary to reduce them to the condition of a paste, the grinding of these blacks is a slow, and by no means an easy, process. The term “grinding” is here used in its strict application, of which an essential condition is that during the process the particles shall be reduced in size. Now, careful examination by means of a microscope fitted with a micrometer eye-piece reveals the fact that ordinary grinding on the usual triple-roller granite mill does not materially reduce the average size of the particles of a pure vegetable or lamp black. Gas black, being more granular in texture to start with, is capable of being reduced more easily. The practical outcome of these considerations is that rollers with an exceedingly smooth face are necessary where pigments are being dealt with whose particles are already in a fine state of division, and this is still more necessary where the pigment, as in the case of carbon, absorbs a very large quantity of oil. The oil forms an envelope or cushion round the particles, and so prevents the full pressure of the rollers from coming into

play. Porphyry rollers, or metal rollers, are therefore the best for grinding the pure forms of carbon, and the latter are more convenient, as they can be subjected to greater pressure without danger of breakage. In the case of paints which contain mineral or bone blacks as their principal ingredients, or which are composed of a base such as whiting, barytes, or gypsum, stained with carbon or lamp blacks, the above special considerations do not apply, and the ordinary type of granite-roller mill is quite suitable.

The great drawback to the use of metal-roller mills is their small output. Fig. 55 represents a diagram of a

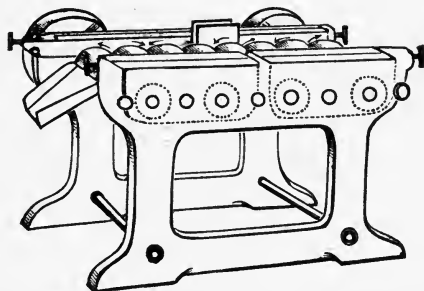


FIG. 55.—Mill with eight steel rollers. The pigment mixed with medium is fed by means of the hopper between the two centre rollers, and is delivered from both ends.

steel-roller mill arranged to deliver at both ends. This method has been adopted with success on the Continent in the grinding of a particular black and materially increases the output, while the cost of handling is also reduced. The powdery nature of the soot blacks renders them unpleasant articles to handle in an open mixing mill, either of the vertical or pan type. Where much mixing is done it is almost necessary to conduct the operation under a hood or in a closed receptacle, in order, amongst other things, to prevent waste. Two simple arrangements for this purpose are shown in Figs. 56 and 57.

In mixing oil with any form of finely powdered carbon great care should be exercised that the two are not permitted to remain long in contact in a partially mixed state, as

spontaneous combustion is liable to occur. A charge should never be left in a mixing mill till the full quantity of medium

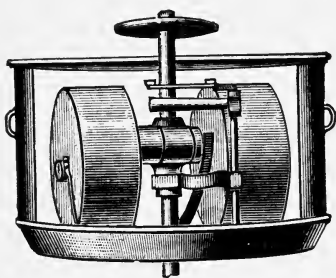


FIG. 56.—Movable hood, with sliding doors, suitable for a pan-mill.

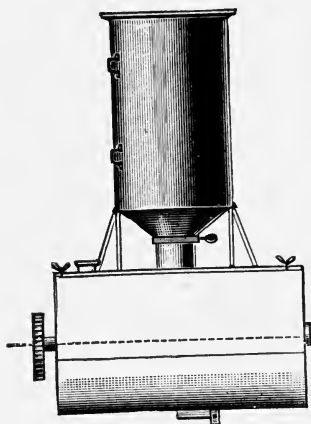


FIG. 57.—Horizontal mixer with tight cover fitted with thumb-screws, and a vertical lamp-black holder. The medium is admitted through a hole in the cover closed with a screw bung.

has been added and the whole charge thoroughly mixed ready for grinding.

CHAPTER IX.

THE GRINDING OF CHEMICAL PIGMENTS.

1. YELLOWS.

THE majority of the pigments in everyday use among paint-grinders which have not come within the scope of previous chapters consists of those whose production depends on chemical processes of a more or less intricate nature. The general term *chemical pigments* may therefore be conveniently applied to them. On such pigments the house painter depends for the greens, blues and bright yellows he requires for his decorating work. In the manufacture of enamels and artists' colours also, pigments of this class enjoy a very large use.

The yellow ochres and raw siennas are examples of pigments which possess a pronounced yellow colour, but they lack brilliancy or "fire," and, in cases where specially delicate or vivid tints are required, recourse must be had to the group of pigments now under consideration.

Attempts have been made, and it must be admitted not without some measure of success, to produce artificially a pigment resembling an ochre in constitution and permanence, but possessed of a brighter and more chrome-like hue.

Mars yellow is a pigment prepared on these lines, and, while of variable composition, consists essentially of hydrated oxide of iron. It is produced by the oxidation of ferrous sulphate (FeSO_4) in presence of a retarding agent (usually alum). Brightness in the resulting pigment is obtained by the utilization of an unstable oxidizing agent such as bleaching powder or potassium chlorate. If the operation is con-

ducted under favourable conditions..(details of which are outside the scope of the present work) a brilliant yellow pigment will be obtained, in stability approaching raw sienna, and working well both in water and oil. There is for some purposes a considerable demand for "old gold" and "russet" tinted colours, and for the production of such hues Mars yellow is very suitable, and its use might with advantage be extended, especially when there is taken into consideration its superiority over chrome yellows in the matter of permanence.

In grinding this pigment in oil it is important to use old and pale raw linseed oil. Poppy oil also may be employed with advantage when it can be procured. It may be remarked at this point that it is of the highest importance to employ only the most carefully selected qualities of oil for the grinding of the finer chemical pigments. Linseed oil made from low-class seed, or containing mucilage, excess of fatty acid or moisture, and boiled oil containing rosin, excess of driers, or cheap adulterants, will, in very many cases, have a seriously prejudicial effect on the colour and the permanence of paints containing certain of the chemically prepared pigments. Hence it is always a safe plan when grinding these colours to use only oils of approved quality and purity.

Any rise of temperature during the grinding of Mars yellow should be avoided, otherwise the colour of the sample will be injured. One of the ordinary types of grinding mill may be employed, and very careful and thorough grinding is necessary as the pigment is liable to contain traces of moisture, which tends, as usual, to cause separation of the oil from the pigment.

Chromes.—The class of chemical yellows which takes first place, both in technical importance and in the variety of shades possessed by its members, is that of the *lead chromes*. These bodies depend for their colouring principle on chromic acid, which, in combination with oxide of lead, forms com-

pounds of varying basicity. The immense variety of shade in which the lead chromes present themselves is a matter of common knowledge, and their manufacture is an important branch of colour making. The paint-grinder need not possess an intimate knowledge of colour striking, but in such matters as the selection and grinding of chromes a general idea of their composition will almost certainly be of service to him.

Although the ordinary chrome yellows of commerce are often considered as consisting of chromate of lead (PbCrO_4), it is rarely, if ever, that this substance is met with in its normal form, as represented by the above formula, even in the purest chromes. As a rule, chromes of the depth of shade usually designated "middle" will be found, unless purposely adulterated, to approximate most nearly to the composition of the normal chromate of lead. The "light," "primrose," or "lemon" shades invariably contain *sulphate of lead*. This must not, however, without careful examination, be set down as an impurity, for in order to obtain the palest shades it is found necessary in the manufacture to employ a solution of bichromate of potash or bichromate of soda to which either sulphuric acid or alum has been added. The consequence is that sulphate of lead is precipitated along with the chromate of lead. An excessive quantity of sulphate of lead, however, or the smallest trace of gypsum (sulphate of lime), barytes, china clay or whiting, indicates a chrome which has most probably been purposely adulterated. "Red" or "orange" chromes are basic in their composition on account of their having been produced in slightly alkaline solutions, otherwise they resemble the "middle" chromes, except in physical texture. A reliable modern work on colour making should be consulted for details on the technology of the chromes.

Although it is inadvisable for anyone but a qualified colour chemist to undertake the examination of a sample of chrome (or, indeed, any of the finer chemical pigments)

with a view to detecting adulteration, a process which has been reduced—one writes it with regret—almost to a fine art, yet it is possible for the paint-grinder to form a tolerably accurate idea of the pigmentary value of the samples submitted to him. A good chrome should possess a rather soft or “soapy” texture, and should not be powdery or granular in structure. It should possess a high staining power and good opacity. Ground in oil, it should form a crisp paste, which should not become soft or sloppy after keeping. Raw linseed oil of good quality should be used in the grinding, no boiled oil or varnish being necessary or advisable. For the pale shades refined linseed oil may be used with advantage. The proportion of oil required varies somewhat, but from 12 to 16 per cent on the weight of the dry colour (equivalent to 14 to 18 lb. per cwt.) is a fair average.

The great failing of the lead chromes is their instability. Prussian blue is sooner or later destroyed in presence of chrome yellow, a point of importance in the fabrication of greens. Quite apart from the well-known blackening effect of sulphuretted hydrogen gas (H_2S) on lead compounds including the lead chromes, sulphurous acid (SO_2) also attacks lead chromate by reducing the chromic acid (CrO_3) to the less highly oxidized form (Cr_2O_3). Thus both the essential constituents of the pigment are open to external influences, and hence on any work on which effective protection from external influences is impossible the lead chromes, as a class, are liable sooner or later to deteriorate.

The basic chromates of lead have come into prominence (in common with certain other basic pigments) during the last few years in connection with controversies regarding the corrosion of iron and steel. It is maintained by some that suitably prepared priming coats containing basic lead chromate “inhibits” the corrosion of iron and steel.

Other metallic chromates are used to a certain extent

in the manufacture of paint, chromate of zinc (ZnCrO_4), or *zinc chrome*, and chromate of barium (BaCrO_4) being the only two which enjoy any considerable use, although chromate of strontium is also used to a limited extent. The latter pigment is less permanent than chromate of barium but possesses more colour. Chromate of barium is principally used as a water colour for which it is very suitable, and it is very permanent though its staining power is low. Zinc chrome is a fine pigment of a pale yellow shade, which is of great use to the painter in compound tints when lead is inadmissible. Brighter coloured greens can be obtained from it than from the lead chromes, and it is excellently suited for the tinting of enamels or white zinc paints, producing a very pure "clean" tint. It may be ground in fine pale poppy oil or in refined linseed oil. Unfortunately although zinc chrome is not liable to the darkening effect in presence of sulphurous gases which is observable in the case of the lead chromes, it is not an altogether satisfactory pigment in protective paints. The chromic acid is somewhat loosely held by the base (ZnO) and under certain conditions decomposition takes place free chromic acid being liberated. This is particularly liable to occur in the case of paints which contain no pigment other than zinc chrome.

2. BLUES.

The only blue pigments of practical interest to the paint grinder are ultramarine blue and Prussian blue. These differ so widely from one another in their composition, hue, and staining power, and in the purposes for which they are respectively adapted, that a few details as to their general characteristics may not be out of place.

Ultramarine blue is a pigment of an unusually pure and brilliant hue. The intensity and purity of its colour, indeed, are the features which chiefly distinguish it, because as regards staining power and capacity to mix satisfactorily

with other pigments it is by no means in the front rank. Further, the tints produced when it is reduced with white-lead or zinc, though suitable for certain purposes, are in general characterized by a want of "life," if it may be so expressed. Prussian blue forms a striking contrast to ultramarine in this respect. Ultramarine is one of a limited number of pigments which are unaltered by strong heat; it is also proof against the action of moderately strong alkalis, but it is destroyed by acids. It is thus pre-eminently suited to act as a blue tinting medium in distempers, but it is with difficulty ground into a satisfactory oil paint. There are purposes, however, for which its colour and permanence recommend it: for example, as a coach-maker's colour. If it is desired to retain the true vivid tone of ultramarine when ground in oil, it is imperative that no foreign material whatever be mixed with it, and it should be ground in pale boiled linseed oil with a little pale varnish of good quality. If, on the other hand, a paint is required which is to be used for ordinary decorating purposes as a self or body colour, the paint will be improved in opacity, as well as in its physical properties under the brush, by the addition, in strict moderation, of a proportion of Paris white or terra-alba (say, 1 part to 3 of ultramarine). Barytes should not be used along with ultramarine, on account of the great difference in the specific gravities of the two substances.

Ultramarine paint used by coach painters is always employed as an undercoating (that is in flat or semi-flat form) which is afterwards varnished. Undercoatings containing ultramarine possess a marked tendency to absorb the varnish applied over them owing to their porosity.

A practical test has shown that a sample of fine ultramarine required 37 per cent of oil on the weight of the dry colour to grind it into paint, while a sample of good quality lime blue took 25 per cent.

Ultramarine is met with in an immense variety of shades and qualities, the lower grades being often referred to as

lime blue. It will be found that the very fine pale shades have frequently a greater depth of colour in oil and greater staining power than the apparently stronger dark shades. It follows, therefore, that the shade of the dry colour is no criterion of the quality of the pigment. The best samples, when reduced with whitelead or oxide of zinc, retain the characteristic ultramarine shade, and are devoid of the reddish tone met with in some of the coarser dark qualities. Even the very palest ultramarine should possess that vivid hue or "fire" which characterizes the pigment, and there should be no approach to dulness or "chalkiness".

Whitelead should not be used in association with ultramarine in paints, but the latter pigment may be safely mixed with oxide of zinc or lithopone,

Prussian blue, in many of its properties, is totally unlike ultramarine. It is a strong stainer, but its opacity is not great. Practically speaking, it is only as a staining colour that the painter uses this pigment, it being the most usual tinting medium in pale blues and greens obtained by the admixture of blue and yellow. Prussian blue cannot be regarded as a permanent colour, although in presence of a large excess of whitelead (as in pale tinted blues) it is somewhat more stable, being protected thereby from external influences. Unlike ultramarine, Prussian blue does not lose its colour in presence of weak acids, but on the other hand it cannot withstand the action of alkalis. It is destroyed by heat, and on that account cannot be used in paints or enamels that have to be subjected to high temperatures. To determine the purity of a given sample of Prussian blue, a strict chemical analysis is necessary; the paint-grinder, however, is usually content to assay it for purity of colour and staining power by rubbing down in oil and in whitelead or oxide of zinc in the usual way. It should be borne in mind, however, that if the pigment is to be used for the finest class of work, a sample of Prussian blue which has been examined only for hue and staining

power may or may not be the most suitable. The preparation of this pigment depends on very delicate chemical processes, and the colour has to be freed from traces of impurities and chemicals which may impair its permanence. In the finer and higher-priced sorts this is done very carefully, but in the lower-priced competitive grades the same care cannot be taken in the manufacture, and the result is a pigment which, though apparently equal to the finer grades, is not so in reality.

Chinese blue, Saxon blue, Turnbull's blue, and Paris blue are species of the genus **Prussian blue**, which, practically speaking, now means any pure pigment consisting essentially of ferro- or ferri-cyanide of iron or of a mixture of the two.

On account of the excellent colour and staining properties of Prussian blue, it is used as a base in several pigments which enjoy a considerable use in paint-grinding, through their being less costly than Prussian blue, while they retain in a large measure its leading characteristics. The chief of these are Celestial blue and Brunswick blue.

Celestial blue consists of a good white sulphate of barium on which Prussian blue has been struck by the usual precipitation process. The proportion of real Prussian blue varies from 5 per cent to 12 per cent. Some very inferior qualities test as low as $2\frac{1}{2}$ per cent, but a good quality Celestial blue may be considered to be represented by a strength of 12 per cent, while 5 per cent is a common strength for a second grade. In the dry state the colour of Celestial blue is a pale blue; mixed with oil, however, it forms a dark blue paint, the precise depth of tint being dependent on the percentage of Prussian blue and on the quality of the base on which it is struck.

Brunswick blue is an article of very much the same nature as Celestial blue, but its base is usually blanc fixé or terra-alba (gypsum) instead of barytes, and it is, as a rule, considered a superior pigment. It contains a higher proportion of real Prussian blue than Celestial blue contains.

The grinding of Prussian blue in oil is a matter that presents some difficulty. The action of this pigment on drying oils, and especially on linseed oil, is a very curious one, inasmuch as the mixture of pigment and oil soon acquires a gelatinous consistency, which ultimately results in the paint acquiring the texture of indiarubber. In this state it becomes useless as a paint. For this reason the medium used in the grinding of Prussian blue must be selected with care. Notwithstanding the difficulties connected with drying (Prussian blue being a pigment which retards drying) which are liable to occur if the grinding medium consists of a non-drying oil, it has for long been a custom in the trade to grind Prussian blue in olive oil or whale oil or a mixture of the two. As only very small quantities of the paste-paint so produced are used for tinting other paints, the non-siccative character of the Prussian blue paint can be overcome by the addition of suitable driers during mixing. Repeated grinding through cone mills is necessary, as the particles of pigment in the finer sorts of Prussian blue are extremely hard and difficult to reduce.

Printing-ink making is a branch of colour grinding in which a large quantity of Prussian blue is used. In this class of work steel or chilled iron roller mills are used, on account of the viscosity of the medium used and the necessity for absolute perfection in the grinding.

The grinding of Celestial and Brunswick blues is not attended with the same difficulties which occur in the case of the pure Prussian blue. The large excess of barytes, blanc fixé or terra-alba which they contain tends to counteract the action of linseed oil on these pigments; indeed, samples of stiff paint made from these materials have an unpleasant knack of turning very soft and sloppy. This can usually be attributed to lack of sufficient pressure on the rollers during grinding. A case, however, occurred where a Brunswick blue containing $12\frac{1}{2}$ per cent. of real Prussian blue was ground

in raw linseed oil, and was thinned ready for use with boiled oil and turps. A tin of the mixed paint was left for nine months, and was then found to have acquired the consistency of guttapercha all the way through. Paints made from blues whose base is barytes are very liable to settle when thinned out and allowed to stand some time. It is advisable therefore, when grinding paint which is to be afterwards thinned, to use the lighter pigment whose base is blanc fixé or terra-alba, and to add a proportion of barytes during the grinding in oil to keep the texture open.

3. GREENS.

The most widely used of all green pigments is that obtained by the mixture in various proportions of lead chrome and Prussian blue. Originally the materials were ground together in the dry state, and the resulting green varied in colour according to the shade of the chrome and the relative proportion in which it was blended with the Prussian blue. To these compound greens the term *chrome green* was applied. This term is confusing inasmuch as it is also and more properly used to describe the pigment which consists of the sesqui-oxide of chromium (Cr_2O_3). A much brighter and finer-looking pigment is obtained, however, when greens of the same composition are prepared in the *wet way*, that is, when the chromate of lead and the Prussian blue are simultaneously precipitated from suitable solutions. By controlling the essential conditions—temperature, concentration, proportion of the various ingredients, etc.—pigments are obtained which present a remarkable range of shade. To these the general descriptive name *Brunswick green* is now applied. The terms “light,” “middle” and “deep” are used to indicate the depth of shade, but, as in the case of the chrome yellows, these are only comparative terms, as each maker has his own shades, which he may or may not be able uniformly to adhere to. The nomenclature of the green pigments is in need of being brought up to

date, as confusion is not altogether absent. Thus the modern Brunswick green just referred to has nothing in common with the green of that name described in many treatises on colours, and which was originally a basic carbonate of copper. Again, the designation chrome green, which is often used as a synonym for the more recent Brunswick green, is also applied, as has been indicated, to the green oxide of chromium (Cr_2O_3).

The paint-grinder has to deal with Brunswick greens of all qualities. Some of the finer sorts consist practically entirely of chrome yellow and Prussian blue. These high-class grades, if ground by themselves in oil, are usually intended for special purposes, e.g. coachmaker's work, and the remarks which have been made with reference to the choice of oil for fine colours apply to the pigments now under consideration. These so-called *pure* greens are good stainers, but they do not possess the opacity of some of those to be described later. Most of the Brunswick green which is used for ordinary paint manufacture consists of pigment struck on a suitable base. The base is usually white-lead, barium sulphate or terra-alba. If whitelead is the base employed, the resulting pigment will possess superior opacity but will lack brightness; if barytes has been used, the colour (assuming that the barytes was white) will be bright, but paint made from green struck on a barytes base will in all probability tend to turn soft after grinding. Greens struck on either barytes or terra-alba are those which the paint-grinder has often to use in the making of ordinary green paint. In cheap qualities of such green pigments, barytes is the usual adulterant. Terra-alba, when present as the base of the dry colour, improves the physical texture of the paint, and assists it to retain the proper consistency, while excess of barytes invariably tends to ultimate *sloppiness*. The objection to both barytes and terra-alba is their poor opacity, and as green paint is usually employed as a body colour this is an important point. By using a proportion of whiting in

the paint this defect may be remedied, but this ingredient must be used with great care, as the least causticity causes it to react on, and partially destroy, the Prussian blue, with the result that the green turns several shades yellower, and in the case of pale shades might be destroyed altogether. Much discrimination therefore is necessary in the selection of the materials for green paint.

The proportion of oil required for the grinding of Brunswick green paint varies according to the purity of the pigment and the base on which it is struck. Fifteen to twenty per cent on the weight of the dry material is not an uncommon proportion of oil, but for low grade material consisting essentially of barytes, a much lower proportion will suffice. Greens of rather low quality struck on barytes are very unsatisfactory materials to grind, the paint having a great tendency to *drop* or turn soft. To obviate this the course that most readily suggests itself is to reduce the quantity of oil. Frequently this is done without regard to the fact that unless a sufficiency of oil is present the grinding must be of an imperfect character. When paint is seen coming off the scraper of the roller mill in flakes, and with a dry spongy appearance, an explanation should be sought for at once. If the grinder explains that it will *drop* or *come together* after lying a little time, that settles the matter. The very fact of the paint softening to this extent proves that it is poor stuff and that it should be condemned. As to the means to be adopted to enable the proper quantity of oil to be used and still retain the right consistency in the paint after keeping, obviously something with a stiffening or setting-up tendency must be added along with the raw linseed oil. Boiled oil is often used instead of raw oil for this purpose, but except in the case of really good quality paints its use is not to be recommended. Varnish and varnish foots are also in request for the same purpose, and frequently have the desired effect, but if used in any considerable quantity these materials, owing to their viscosity, interfere with the

grinding, and an additional drawback is that their presence is liable to cause the colour of the paint to darken. One of the best stiffening agents known is the foots deposited from boiled oil which has been boiled in the old-fashioned way with lead driers. When this material is procurable it frequently enables the paint-grinder to obtain, from comparatively second-grade materials, a crisp paint, which tends to stiffen on keeping. It is unnecessary perhaps to point out that these foots are exceedingly powerful driers, and that they should be used with caution. Three to seven lbs. stirred into a gallon of raw linseed oil and added to five cwt. of the paint towards the end of the operation of pugging is an ample proportion in most cases. For other fine colours besides green it is often useful to have at hand a convenient stiffening agent for use in cases in which the paint is liable to soften after grinding. If the foots referred to above are too highly coloured for use with the pigment under treatment, the same result can be obtained by boiling a small quantity of linseed oil at as low a temperature as possible with pale litharge in excess, pushing the process a good deal further than would be done in ordinary oil boiling. The resulting thick strong-drying oil may be used in small quantities in the grinding to communicate the desired crispness and stiffness to the paint. Oil boiled with manganese driers should not be used for this purpose.

In assaying Brunswick greens for staining power it is important to remember that the nature of the base on which the colour has been struck has a considerable influence on this property. Thus two samples of green containing the same percentage of real green (chrome *plus* Prussian blue) will show different staining powers if one is struck on barytes and the other on whitelead. In the latter case the pigment, if judged by this test alone, would come out second, while the probability is that it would make the better paint. Therefore, in deciding between competitive samples, the composition must always be taken into account.

These notes on the Brunswick greens apply with but slight modifications to the exceedingly numerous, and often fancifully named, greens of similar composition—such as royal greens, emerald-tinted Brunswick greens, etc. In some cases the chrome part of the pigment may be zinc chrome instead of lead chrome, and zinc oxide may even be used as a base on which to strike the colour. If so, it has the result of enabling an exceedingly vivid and clean colour to be produced, which is of great use in the making of bright green paints, in tinting enamels, etc.

Emerald green is at once one of the most beautiful and one of the most unsatisfactory pigments with which the paint-grinder has to deal. In the first place, as arsenic enters largely into its composition, and as it is moreover a very dusty colour, it must be handled with the very greatest care. Respirators and gloves should be worn by workmen handling it in the dry state. One of the most frequent sources of trouble connected with the handling of pigments of a toxic character is the liability of the workmen to absorb particles from the hands. The action of passing the naked hand across the face or mouth is such a natural and frequent one that it is done involuntarily, often with serious consequences. The fact of having a glove or covering on the hand is a very effectual method of preventing this, hence the advice is offered : When work is dangerous enough to render a respirator necessary, let gloves of a suitable pattern be worn also.

In spite of its brilliant hue emerald green possesses very little staining power ; therefore when it has to be used it should on no account be mixed with any other solid material, otherwise its characteristic colour will be lost. Pale boiled linseed oil, with a small quantity of pale oil varnish, should be used to mix with the pigment. The mixing should be very thorough. The process should be conducted in a mill provided with a dust-proof cover, and the proportion of oil should be carefully regulated. The less grinding the paint

is subjected to the better. It may be passed once through the rollers, and even then the pressure should be light. If excessive or prolonged pressure is brought to bear on this pigment the colour will be seriously affected, and it will lose its brightness, ultimately becoming nearly white. It is impossible, therefore, to make a properly ground paint with emerald green; all that can be done is to get a well-mixed paste which will retain a uniform consistency. Emerald green is capable of application in cases where Brunswick green would be inadmissible. Thus it is suitable for use on surfaces exposed to the action of salt water. Brunswick green would be useless for this purpose. It is for a few special purposes of this kind, and for special decorative work, where its vivid, transparent hue is required, that it is specially adapted. The high price of emerald green should render buyers careful to test every parcel for purity. The great aid to sophistication of this material is aniline dye. So-called *imitation emerald greens* are sometimes offered, consisting of some white base or native green earth stained with a dye of the correct shade. In fairness it must be said that as a rule these articles are offered on their merits, and simply to meet the demand for something cheap. From the paint-maker's point of view they should be studiously avoided. Carefully chosen emerald-tinted Brunswick or zinc greens will as a rule supply the means for making second grades of paint possessing more or less of the emerald hue.

Bronze greens.—These form a large and useful class. In composition they are essentially Brunswick greens tinted to the required depth with such materials as umber, chrome, and black. Variations of the bronze greens are *quaker*, *saxon* and *invisible* greens—the latter being nearly black. A wide range of colours can be obtained in the bronze greens, and highly decorative shades are produced from them when they are used as tinting colours. There should be no pigment of the nature of barytes, whiting, or terra-alba in

their composition, as the presence of such materials greatly detracts from the natural rich tone of the green and produces a chalky effect. Indeed it is only in inferior grades that such ingredients are met with. Bronze greens are usually of lower specific gravity than Brunswick greens, and they also absorb a considerably larger proportion of oil in grinding—in many cases twice as much. Dark bronze green is more likely to be adulterated than the lighter shades. The reason probably is that in the dark shades a larger proportion of Prussian blue is necessary; and this pigment being a very powerful stainer it can be made to mask the presence of such cheapening agents as barytes or terra-alba, or the blue used (and this is especially the case in deep bronze green that has been prepared entirely in the dry way) may be Celestial blue, which is itself largely barytes.

In practice the grinding of a good quality medium shade bronze green will be found to resemble to some extent that of English umber. It is important that the oil and pigment be very thoroughly incorporated previous to grinding, and the grinding itself must be thorough. Experience has shown that when the paste-paint turns hard on keeping it is usually the fault of the grinding, and that when it turns soft the dry pigment is to blame. Of course it is assumed in both cases that the quantity of oil was correctly judged at the time the paint was made. Raw linseed oil gives, on the whole, better results than boiled oil, and a small quantity of the litharge boiled oil referred to under Brunswick green may be added. It should be remembered in preparing bronze green paint to match a sample tint which has already dried, that this colour dries out several shades darker than it appears when thinned in oil. The presence of varnish increases the difference.

Lime green, Mineral green, and Green verditer are pigments whose uses are so restricted, especially as oil colours, that it is unnecessary to do more than refer to them here.

Few, if any, pigments as a class possess greater interest

than the greens. Chemists and inventors have again and again been attracted by the desire to imitate one of Nature's most beautiful colours. Such names as Scheele, Casselman, Gentelé and Guignet will be remembered in the history of colours, though they find no place nowadays in the colour price-list or the paint-works.

4. REDS.

In addition to the red ochres and the pigments whose base is ferric oxide, which have been treated of in a former chapter, there are numerous red pigments in everyday use which may properly be classed as *chemical* or *fine* pigments. A few notes on such of these as the paint-grinder is likely to have to deal with may not be out of place.

Red lead, or Minium (Pb_3O_4), is not ground in oil to any large extent, its intense drying tendency rendering it unsuitable for this purpose. It is a common constituent of priming paint for new woodwork, and its excellent anti-corrosive properties also cause it to be used as a protective coating for ironwork. Many priming paints applied on ironwork, and especially those made from oxide of iron, tend to flake ultimately. Red lead, when applied under suitable conditions, does not do this, and therefore oxide paint can be applied over it. Except for such uses it is mainly employed to make lutes or cements for certain purposes. Thus *jointing putty* consists of whiting, linseed oil and red lead. A cement used to pack boiler manhole flanges, etc., is made of Venetian red, oil and red lead. In all cases where red lead has to be ground in linseed oil it should be ground fairly soft, and only enough should be prepared for the particular purpose for which it is required. If left in contact with a drying oil for a short time the pigment promotes drying to such an extent that the whole mass soon becomes quite hard.

The great opacity of red lead enables adulteration to be practised unless the buyer is on the alert. White barytes

and ground glass are the usual adulterants, and moderate additions do not seriously affect the colour. A more subtle method is to mix the red lead with barytes which has been stained with aniline dye. In this way enormous quantities of cheap material can be added without sensibly altering the colour of the dry material. Fortunately, sophistication of this kind is easily detected, as pure red lead is completely soluble in warm dilute nitric acid on the addition of a small quantity of cane sugar or other reducing agent.

Different samples of red lead vary greatly in the brightness of their colour. This is usually due to differences in the conditions under which the roasting has been conducted, and to variations in the quality of the pig lead. Sometimes an artificial bloom is communicated to red lead of poor colour by washing it in an alcoholic solution of eosin or erythrosine. The physical texture of the pigment also varies in different samples. This point is of importance when the red lead is to be used as a constituent in a mixed priming paint.

Orange lead has essentially the same composition as red lead, but its colour, as its name indicates, is somewhat yellower. Just as the roasting of metallic lead under certain conditions produces red lead, so the roasting of the hydrated carbonate of lead (whitelead) yields the orange variety.

Vermilion.—This remarkably fine, bright pigment, which consists of sulphide of mercury (HgS), can be prepared according to two methods—the dry and the wet. Vermilion made in the dry way is either prepared in accordance with the old Dutch method or is imported from China, where large quantities of mercury are yearly converted into vermilion. The high price of vermilion prevents it being used except for special purposes, and for high-class work, and as a rule it is bought by painters and other consumers in the dry state. When ground in oil it tends to separate out again, owing principally to the physical texture of the material. The use of thickened

linseed oil will counteract this tendency, but if the paint is to be used at once it is better to grind it in pale Baltic oil free from sediment. Too much pressure should not be used during grinding, as it tends to injure the colour. In spite of the rich colour of vermilion, and its consequent value as a decorative material, it cannot be described as a permanent pigment. Heat destroys it, and on exposure to ordinary atmospheric influences the pigment readily blackens, owing to its conversion into the allotropic black sulphide of mercury. The change in colour of the red into the black sulphide is an instance of a purely physical change as distinguished from a chemical one. For this reason surfaces painted with vermilion should always be varnished.

It is customary for railway companies, and other large buyers of vermilion, to specify that it shall contain 98·8 per cent of mercuric sulphide. This allows the small margin of 1·2 per cent for commercial impurity—chiefly sulphur and iron.

Antimony vermilion.—Artificial sulphide of antimony (Sb_2S_3) is a pigment of some value for paint making, and it has been proposed to use it as a substitute for vermilion. The pigment when properly prepared possesses a bright scarlet colour, and it works well in oil. Its use is by no means so general, however, as might be expected, although it is met with as an artist's tube colour. Pale poppy oil is the best medium in which to grind the material.

Persian red.—This name is usually applied to basic lead chrome, the properties and grinding of which have been described under "Yellows". This substance is an instance of many cases in which the name of a *colour*, as distinguished from that of a *pigment*, becomes associated with a particular material, which has frequently no similarity except in hue with the substance to which the name was originally applied. So with Indian red, which was originally the name of a *colour*. The name was then used to describe that pigment which was most used to produce this colour, and accordingly

when Indian red is spoken of now, an oxide of iron of a particular shade is invariably meant.

Chinese red is also a chromate of lead. It often possesses a rather dull colour, and is always less scarlet in tone than Persian red. The term Chinese red has come to be associated with a particular shade, and numerous pigments bearing the name Chinese red are on the market whose base is not chromate of lead at all. Others again consist of red chrome, which has been brought to the proper shade by treatment with an aniline dye.

As regards grinding in oil, all these chrome pigments may be treated in the manner described under the heading of "Chromes".

Vermilionette is a pigment which was one of the earliest substitutes for vermilion. As originally prepared, it stood midway between a lake and an ordinary metallic pigment, its base being red or orange lead, on which an eosine lake was precipitated. Many vermilionettes, however, are merely eosine lakes diluted to a greater or less extent with starch or china clay, or other similar inert substance. The pigment varies very much and is very fugitive, light having a powerful influence on it. Paints of the shades known as *signal red*, *post office red*, and *royal mail red* were originally prepared from one or other of the numerous vermilionettes, but more recently one or other of the more permanent so called *fast-red* pigments have come to be adopted as the base of these shades in most instances. The great advances which have taken place in the manufacture of red pigment lakes have wellnigh ousted the old-fashioned vermilionette from its position.

Vermilionettes and fast-reds vary greatly in opacity and staining power, as well as in their permanence towards light and other external agencies. Before selecting a sample of the pigment for paint-grinding it is well to test all three properties carefully. As a rule it is found more difficult to obtain a good scarlet shade than a blue or crimson one, and

the yellower shades are to be preferred for paint-making. The addition of barytes to the paint has the effect of accentuating any blue tint; hence if the pigment has to be reduced it is especially desirable to secure a yellow shade.

The opacity or body is best observed by mixing the same weight of two or more samples with equal quantities of oil, and then placing a drop of the mixture on a sheet of glass and rubbing it out with a circular motion of the finger. Practice enables one to obtain by this means films of the same thickness, and by holding these against the light a very good idea of the opacity of the sample can be obtained.

This method may be applied to any pigment or paint which is sufficiently transparent to enable moderately small differences to be observed. Thus vermilionette, emerald green, and paints or pigments that have been adulterated with transparent substances, such as barytes, can be very well compared in this way. On the other hand, bodies of great opacity, such as whitelead, lead chrome, etc., yield such dense films that small divergencies cannot be observed.

The simplest way to determine the action of light on pigments or paints suspected of being fugitive is to thin out a portion of the sample under examination with linseed oil and turpentine, the relative proportions of the two liquids being so adjusted as to yield a surface which is *just* flat, and no more. A suitably prepared board or panel is then painted, and allowed to dry in a cool, dry, *dark* place. It is then divided into two portions, one of which is kept in the dark and the other exposed to direct sunlight. Comparison of the two portions at intervals will result in showing to what extent the material in question may be expected to change colour under the influence of sunlight. The scope of the experiment may be increased by varnishing a part of each of the two sections of the board, and noting whether the colour stands better through being protected in this way.

All vermilionettes with any pretensions to good quality are strong driers, as lead salts in one form or another are

practically always present in them. For this reason only raw linseed oil should be used in the grinding; no varnish or varnish foots of any kind is admissible. Boiled oil even should not be used, especially if it has been boiled with a resinate drier. Whole casks of paint have been known to turn quite hard through want of attention to this point. If a cheapening material must be used, good white barytes is perhaps the least objectionable.

The mixing of the pigment and the oil should be very thorough, and the horizontal mixer is well adapted for the process, as this form of mill quickly mixes a soft material like the one now under consideration. During grinding on the ordinary three-roller granite mill the pressure should be as light as possible. Heavy pressure and a rise in temperature are sure to injure the colour. Owing to the poor staining properties of vermillionette it is very important to see that the mixing mill, rollers, and all utensils used in connection with the grinding are clean, as the smallest trace of a colour such as black or green will ruin a large batch of vermillionette paint. The most careful millmen are sometimes apt to lose sight of points like this.

Bright Red Paints.—There is a considerable demand, especially among buyers of paint thinned ready for use, for bright red shades. The general buyer of ready-mixed paint has often exceedingly vague and undefined ideas as to the relative cost of pigments, and is therefore unwilling in many cases to pay more for a shade which can perhaps only be satisfactorily produced from a madder lake than he would for an ordinary oxide of iron colour. The result is that the paint manufacturer, often against his inclinations, is compelled to offer, as bright red paints, oxide paints tinted with vermillionette, or with cheap carmine or eosine lakes, although he is well aware that not only is the colour extremely fugitive to light, but that the iron base of the paint itself is by no means a desirable companion for many lakes. Rose-pink is another material sometimes used to communicate to

purple oxide or Indian red a rich maroon shade (Tuscan red). The effect is only a temporary one, however, fading and general deterioration always ensuing.

The fact is, it is not advisable to tint oxide of iron paints at all. Oxide of iron under normal conditions can be relied on to give certain definite results. The introduction of a miscellaneous assortment of highly active chemical colours only unfits it for doing what it would otherwise do with success.

The preferable procedure in making up bright red paints when cost has to be considered is to start with white barytes, and to add the maximum of vermilionette or whatever red lake pigment it is desired to use that the cost allows. Certainly the opacity of the paint will be poor, but this is perhaps, on the whole, a lesser evil than those previously referred to, and moreover brighter tints can be obtained in this way.

5. LAKES.

Although lake pigments of many hues are used for special purposes in paint-grinding, only those of a more or less red colour are used in any considerable quantity. As the term *lake* has come to be applied with some want of precision, a few words on the composition of the leading classes of lake pigments may not be inappropriate.

In general terms, true lakes may be defined as "insoluble pigments obtained by precipitating solutions of organic colouring matters with metallic salts" (J. J. Hummel). Thus madder lake is obtained by precipitating with sodium carbonate the extract produced by digesting madder with alum. Cochineal lake (carmine) is obtained by an analogous process. These two magnificent pigments, along with the lakes obtained by precipitating the colouring matter of various coloured woods, etc., with metallic salts (*e.g.* Brazil-wood, the base of Vienna lake and rose-pink), are examples of true lakes.

A very large proportion of the lakes now in use are

derived, not from what may be termed natural sources, like those just referred to, but from artificially prepared colouring matters whose origin is coal-tar. Alizarin is typical of such bodies, and alizarin and purpurin lakes can be produced in a great variety of red and pink shades.

At the present time, also, a large number of so-called lakes are manufactured which do not conform to the definition of a true lake already given. They consist in reality of a base such as china clay, starch, precipitated sulphate of barium, hydrate of alumina, etc., which base, by virtue of molecular attraction or weak chemical affinity absorbs and holds, with a certain degree of tenacity, various colouring matters. Many so-called lakes consist simply of a carrier of this nature saturated with a soluble dye. It is obvious that the pigmentary properties of such a "lake" cannot be compared with those of a pigment whose whole mass consists of precipitated colour. At the same time, it should be remembered that a true lake may contain considerable quantities of inert material distributed through its mass. Thus fine lakes may contain zinc oxide, oxide of tin, hydrate of alumina, etc. These substances, however, are to be considered as being present for some specific purpose—either as diluents for the purpose of procuring a desired shade, or as by-products, so to speak, produced during precipitation.

From what has been said it will be understood that the assistance of a properly qualified paint chemist is essential in testing, examining and matching such highly complex substances as lakes.

Lakes which are to be used as paint pigments must possess a full rich *colour*. There should be no approach to chalkiness, on the one hand, or to dulness or earthiness, such as is associated with even the brightest oxide of iron pigments, on the other.

The *opacity* and *staining power* of lake pigments are usually considerable. The pseudo-lakes possess these properties in a much reduced degree.

The *permanence* of lakes varies greatly; very few of those commonly used in the fabrication of paints and enamels are really permanent, and many are exceedingly unstable, although those colour makers who specialize in this department are yearly improving the permanence of their products. They are now able to tell the buyer, for example, under what conditions a particular lake will not be permanent, this is a great step in advance of what occurred years ago. It is advisable, before adopting a particular lake, to test it carefully under varying conditions as to exposure to light, action of oil and turpentine, effect of alkalis and of other pigments, etc.

Finally, every lake which is to be used as a paint material must be insoluble in oil and turpentine, otherwise, instead of obtaining a true paint, we obtain simply a tinted varnish whose opacity is probably nil. When a lake is soluble in the medium surrounding it, it is said to "bleed," and this defect shuts out many lakes from being used as pigments. But a lake may bleed in one medium and not in another, and therefore the paint-maker is often well repaid in expending some time and trouble in designing a suitable medium for his lake pigments.

The grinding of lakes in oil is, as might be supposed from the foregoing remarks, a process which requires careful attention and nice judgment. Only carefully adjusted mediums should be used, and as most lakes are rather poor driers—some indeed are notably defective in this way—it is usual to grind them in a suitably prepared varnish. The varnish must be selected with care, as some resins are acted on more than others by certain constituents of the pigment, while the colour is liable to be more or less affected. On account of the fine state of division of the particles composing the pigment, the same rules apply as have been indicated in the case of other finely divided pigments. Grinding machinery for fine pigments generally is discussed in some detail in connection with the grinding of pigments in water and turpentine.

CHAPTER X.

THE GRINDING OF PIGMENTS IN WATER.

PAINTERS and decorators employ certain pigments ground in water for specific purposes, chief among which are the tinting of distemper or water-colour paint and the staining of woodwork. The following list includes the typical pulp colours used in the painting trade. Numerous other pulp colours are used in paper staining and in kindred industries, but these lie outside the limits of the present volume :—

Burnt and Raw Sienna in water.

Burnt and Raw Turkey Umber in water.

Vandyke Brown in water.

Venetian Red in water.

Drop Black in water.

Dutch Pink in water.

Lakes (sundry) in water.

Burnt sienna in water may be regarded as a typical water colour for painters' use. It is important in selecting burnt sienna which is to be ground in water to see that it is not hard, gritty, or siliceous in composition, as siennas of this nature are difficult to grind and exert a serious wearing action on the grinding plant. A soft, voluminous pigment yields the best results, and will also be found to absorb and retain the water better. It is preferable to allow the pigment and water to remain in contact for some time before mixing and grinding take place. In this way the particles become disintegrated, and grinding is rendered much easier. The water should be boiled before being placed in contact with the pigment, and it is important to see that only pure

and clean water is used, and that it has not been heated in oily or greasy vessels, or by direct steam containing oil, such as exhaust steam from an engine. If the water contains organic matter it will inevitably induce decomposition, to the serious detriment of the ground pigment. A cask of sienna ground in water will often be found, after it has stood some time, to contain portions the colour of which has changed from the characteristic sienna hue to a dirty yellowish-green or drab.

For mixing the pigment and water preparatory to grinding, the type of mill described on pages 38 and 39 will be found very suitable. This mill gives very good results in cases in which a comparatively large proportion of liquid, whether oil or water, enters into the composition of the paint. Thus for ochres, siennas, umbers, and the like it is well adapted, and thorough and expeditious mixing can be effected by its use. On the other hand, for the stiffer colours it is not so satisfactory. The dry pigment and water may be placed in the pan, and allowed to remain for some hours before grinding, but frequently when a parcel of several tons has to be ground time will not permit of this, and the mixing therefore must be performed all the more carefully.

The proportion of water required will vary according to the quality and fineness of the dry powder. A fine soft burnt sienna will require nearly its own weight of water; lower grades take less. Before the exact quantity of fluid required can be judged a small portion of the paint should be passed through the rollers. A good sienna paint containing an approximately correct proportion of water will emerge from the rollers stiffer than it was before it went in, whereas a poor sample will turn soft during grinding.

The grinding of water colours may be completed on the ordinary three-roller mill, and most of these paints are finished in this way. Under efficient superintendence very excellent results are obtained, and a great saving in time is undoubtedly effected in comparison with any other method

of grinding. Considerable skill, however, is necessary in setting rollers to take water colours, and it is a question whether, on the whole, better results are not obtained by the use of the "slow-and-sure" system—the old-fashioned flat stones—or mills based on that type.

The theory of grinding by means of the flat-stone type of mill is well illustrated by the common operation of rubbing down a portion of colour in oil, water, or turps, by means of a muller, on a glass or porcelain slab. The phenomena then observed are practically identical with those seen in larger operations in which flat stones are employed.

The following are the chief points worthy of attention:—

(1) The ground pigment is gradually forced centrifugally from the under-surface of the muller, and collects on the outside edge; hence in power-driven plant an efficient scraper to remove the ground mixture is necessary.

(2) The relative proportion of fluid and dry colour must be carefully adjusted. Too much liquid (oil, water, turps, etc.) favours imperfect grinding, a large proportion of the solid particles being forced from between the grinding surfaces, so that the process has to be repeated again and again before a perfectly homogeneous ground paste or pulp is obtained. If, on the other hand, the liquid is insufficient in quantity, the grinding surfaces will become clogged, and great friction will be produced without a corresponding amount of grinding taking place.

(3) The grinding effect is influenced by the nature of the grinding surfaces. Thus a *smooth glass* muller working on a smooth glass plate grinds a sample of, say, oxide of iron with difficulty, whereas if the surfaces are *ground glass* the pigment is reduced more easily. Similarly, the hardness and texture of mill-stones have an important effect on the result. According to the class of materials with which they will have to deal, mill-stones are variously made of French burr, lava, grey, or Derby Peak stone.

The cutting of the channels or grooves in mill-stones is

a matter of importance, as the angle, depth, and disposition of these influence the output of ground colour materially. Engineers and manufacturers of mill-stone plant have bestowed great attention on this point. Fig. 58 illustrates a mill-stone with grooves cut after an approved pattern.

The principle of the flat-stone mill has been applied to the making of compact and portable mills, in which the

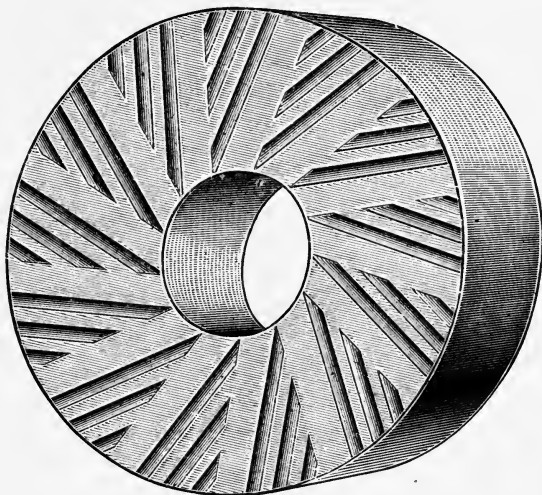


FIG. 58.—One of the stones of a flat-stone mill, showing a system of grooving. grinding surfaces are either metal, as in the cone mills which will be described in Chapter XIII, or stone, as in the type illustrated in Fig. 53. A similar mill is shown in Fig. 59 with top stone in position for work. This mill is also fitted with a cold-water cooling arrangement, which is a characteristic feature of much of the American paint-grinding machinery, and is peculiarly suitable in connection with the grinding of fine chemical colours in oil, and for turpentine colours. For grinding pigments in turpentine, naphtha, spirit, or varnish, the triple-roller granite mill is not the best, owing to the serious loss through evaporation which is inseparable from its use. The iron cone mill, or a water-cooled mill similar to that indicated in Figs. 53 and 54, will probably be

found, on the whole, most satisfactory for this class of work. Mills of this type are, however, rather difficult to clean out when changing from one colour to another; hence, if the volume of work permits, it is advisable to have a mill or a set of mills for each colour. Another point worthy of atten-

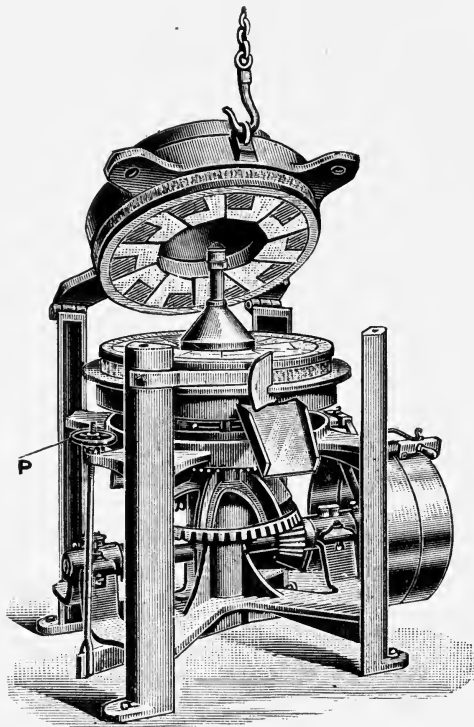


FIG. 59.—Horizontal stone mill. The upper stone is fitted in frame, which is hinged, and can be lifted as shown. The wheel P, with rod and lever attachment, regulates the pressure.

tion is that these mills must be treated carefully during work. The speed, the pressure on the grinding surfaces, the adjusting of the scraper or knife, are a few of the details to which the workman will have to attend if satisfactory results are to be obtained.

Another type of water-cooled mill has been described on page 75. This mill is of the horizontal three-roller

form, and as the water, by means of an ingenious arrangement, circulates through the rollers, very efficient cooling is effected. The rollers are necessarily of metal, and the output of ground material is therefore small. Certain lakes and fine chemical colours, which tend to undergo change if heated, also varnish paints and colours in turpentine, may be advantageously ground on a mill of this description. In the case of paints containing turpentine or other volatile constituent, loss through evaporation is inevitable with any form of three-roller mill, on account of the large surface exposed.

The remarks on the grinding of burnt sienna in water may be applied with but slight alteration to the grinding of *raw sienna* and the *umbers* in water. *Vandyke brown* presents features which must be referred to in detail. Nothing, indeed, more conclusively proves whether a given sample of Vandyke brown is a true bituminous earth or a tinted imitation than its behaviour when ground in water (see also Chap. VI.). A true Vandyke or Cassel brown forms, when ground to impalpable fineness in water, a pulp of jelly-like consistency. Mixed with water and ground in a mill the mixture first assumes the thickness of cream, but after standing it stiffens so that it can be cut with a knife. Spurious Vandyke brown, on the other hand, does not stiffen, and the water, being very loosely held by the particles of oxide of iron and lamp black (which usually form the base of such materials), readily separates, and leaves the paint hard and lumpy.

The amalgamation of the water with the dry colour will, when true Vandyke brown is being used, be greatly assisted by dissolving in the water a small quantity of carbonate of soda. One oz. of the latter is sufficient for 28 lb. of Vandyke brown, and if the water is boiled, placed in contact with the pigment while hot, and the mixture left some hours before it is ground, the result will be better; 28 lb. of good Vandyke brown will require from 28 to 35 lb. of water.

Since Vandyke brown in water is often used to stain woodwork previous to varnishing, and as the presence of alkali is apt to act prejudicially on the varnish, it is open to question whether it is altogether advisable for the paint-grinder to introduce alkaline matter; at the same time, the fact remains that doing so assists the grinding.

Chemical and fine colours, lakes, etc., are ground in water to a limited extent. As a rule they should be ground rather stiff, as most of them tend to "drop" on standing. In the case of certain chemical colours like the lakes it is essential that the water should be free from impurity. Water containing lime, or traces of iron, is exceedingly liable to injure delicate pigments. Certain pigments, for the same reason, cannot with safety be ground on iron or steel rollers, so that here, as indeed in every department of paint-grinding, the composition of the pigment, and of the medium in which it is to be ground, must be taken into account in deciding the treatment to which the material will be subjected.

A practical difficulty in connection with the storing in bulk of water colours in pulp form arises from the difficulty of preventing hardening due to the evaporation of water. The evaporation of moisture, even at ordinary temperatures, from the surface of materials composed of minute particles is very considerable. In certain cases, e.g. burnt sienna, where the material has been rendered anhydrous by a roasting process, water may be chemically absorbed by certain constituents of the material itself, such as lime.

A thin film of glycerine or of glycerine and water spread over the surface of colours ground in water will prevent surface evaporation. Some manufacturers even introduced a small proportion of glycerine into the water used in grinding.

EMULSION PAINTS.

A comparatively modern development in paint-making is the preparation of paints which contain a proportion of

water as an essential constituent, the water being held in suspension by the presence of an emulsion which acts as a carrier or binder of the water and the oily medium respectively. Extreme forms of such paints are found in certain of the well-known water-paints or washable distempers in which the medium in which the pigments are ground consists of an emulsion which varies greatly in its composition—but which usually contains a proportion of emulsified oil, a binder consisting of size, glue or casein and a large quantity of water. On the other hand an emulsion oil paint may contain only 5 per cent of water introduced partly for the purpose of cheapening the paint, and partly in order to facilitate the production of a flat, or semi-flat wall finish which finds a large and extending use in certain classes of decorative work.

A full discussion of the materials which are included in the category of water-paints and emulsion paints would constitute a dissertation on a highly specialized brand of modern paint technology and no attempt is made here to deal with this subject except in the broadest possible way, there being no such thing as uniform or conventional practice among paint manufacturers in these matters.

The emulsifying agents employed are silicate of soda, borax, alkaline carbonates, lime water, and magnesium carbonate. If any one of these materials is beaten up in presence of water with linseed or other vegetable oil (care being taken that the oil is in considerable excess) there is formed a true emulsion, that is an exceedingly intimate mixture of oil and water to which further additions of either oil or water may be made without the emulsion breaking up into its constituent parts. The addition of glue, size or casein in suitable proportion and in a suitable form assists the formation of the emulsion and provides a more or less permanent and elastic binding medium, the result being that when the complex medium so produced has been mixed with pigment a paint is produced which, after it has been

applied to a surface, dries (chiefly by evaporation of the water, but partly also by oxidation of the vegetable oil) with a uniform flat or semi-flat surface. The whole manufacture of water paints is based on these principles, but the variations and modifications which can be introduced are, as will readily be appreciated, very numerous. Notes on such paints would not be complete without reference to lithopone, which is used to an enormous extent as the pigmentary base of most of the best water-paints now on the market. As the base of flat or semi-flat 'wall-finishes' this pigment has an apparently unlimited field before it.

The materials are mixed sometimes in horizontal mixers sometimes in edge-runners, and various types of mills are employed for grinding the paste. Very often the grinding obtained in an edge-runner mill of the positive driven type is all that is necessary, and it may be that in the case of materials which have to be mixed and ground hot (in order to prevent solidification of some of the constituents) a mill provided with a water-jacket (as in Fig. 6) has to be used. Other formulæ do not require special precautions of this nature.

An emulsion oil paint must be so designed as to carry the 5 per cent or so of water which it contains without undue risk of the water separating out. This involves the use of specially selected pigments and a suitably designed medium. The presence of certain materials such as carbonate of magnesium and asbestine is beneficial, as they have the effect of maintaining the whole mass in an emulsified state and of preventing settling.

CHAPTER XI.

THE GRINDING OF PIGMENTS IN TURPENTINE, GOLD-SIZE AND SPECIAL MEDIUMS.

THE grinding of pigments in turpentine and other special mediums may legitimately be considered as a department of paint-grinding. In decorative painting, ornamentation having a flat or dead surface is frequently introduced. The colours used for such work, *flattening colours*, are of fine quality, and are usually ground in a medium consisting largely of turpentine. Ground colours intended for use on surfaces which are to be ultimately varnished, as in coach-maker's work, usually contain a greater or less proportion of turpentine, so that the preparation of turpentine paints is a matter which falls within the scope of the paint-grinder's business.

It should be remembered that although turpentine is the preponderating constituent of the medium in which the pigments are ground in the case of paints used for the purposes mentioned, it is rarely used alone, but is usually associated with varying proportions of oil, varnish, or gold-size, all of which have an important bearing on the final result, and in introducing which the paint-grinder must be guided by certain definite principles. If a pigment were ground in turpentine only, the ground colour would, after being painted on any surface, flake off, owing to the volatilization of the turpentine. Hence a proportion of binding material must be introduced. Gold-size, or as it is frequently termed nowadays, grinding japan, is a substance which is largely used for this purpose, and the quantity required will be regulated by the nature of the

pigment. It is as a rule advantageous to use a proportion of raw linseed oil in addition. The object of the latter is twofold. It gives a certain amount of elasticity to the paint and so tends to prevent cracking, and it prevents excessive evaporation of the turpentine and brings the drying more under control. The proportion of oil which should be used varies with different pigments, and will be regulated by the physical texture of the pigment as well as by its chemical composition. The result that should be aimed at in preparing a good turpentine colour is to obtain a paint which, when laid on a suitable surface, will dry perfectly flat, and yet retain sufficient elasticity to prevent cracking, and present a non-porous surface capable of being varnished.

There are cases in which pigments are ground in turpentine or other volatile spirits only. Materials prepared in this way are as a rule intended for some special purpose and have to be mixed with some medium. In such cases means should be adopted to limit loss of the spirituous grinding medium through volatilization as much as possible. As a general rule it is better to grind in a non-volatile medium and to thin with the volatile medium afterwards than to reverse the process, but cases occur in which the former procedure cannot be adopted.

The two points to be specially attended to in the grinding of pigments in turpentine or gold-size are thorough reduction of the particles of pigment to a uniform impalpable paste, and the prevention of loss through evaporation of turpentine. The remarks already made with reference to the grinding of water colours cover both these points.

Practically, every pigment used by decorators finds some use as a turpentine colour; some, however, are in more general demand than others. A few of the most important are referred to below, attention being directed to the principles that would regulate the relative proportions of turpentine, oil and binding material (gold-size).

Drop black in Turpentine is perhaps the most widely used turpentine colour. The powdery texture of the pigment and its inferior drying properties necessitate the use of a fairly large proportion of gold-size, and very little, if any, oil. The following are average proportions: drop black (dry), 55 per cent; turpentine, $43\frac{1}{2}$ per cent; gold-size, $1\frac{1}{2}$ per cent.

Drop black in Gold-size.—The suggested proportions are—drop black, 46 per cent; gold-size, 46 per cent; raw linseed oil, 8 per cent; the last-named ingredient gives elasticity and keeps the drying under control.

Prussian blue in Turpentine.—The chemical properties of Prussian blue render the use of gold-size inadmissible. Drying oils also cannot be used (see Chap. IX.). A suitable mixture would be—Prussian blue, 58 per cent; turpentine, 37 per cent; olive oil, 5 per cent.

Chrome in Turpentine.—Owing to the pronounced drying properties of the chromes, the introduction of gold-size, or any varnish-like material, is attended with risk of undue hardening. The proportion of oil should be increased considerably. Satisfactory results will be obtained if chromes are ground in a mixture of 3 parts turpentine and 1 part linseed oil.

Brunswick green, Indian red, Sienna, Umber, Rose-pink are a few other pigments in general use as turpentine colours. The principles that govern the grinding of these are similar to those which obtain in the case of the colours already referred to.

THE USE OF VOLATILE SPIRIT IN PAINT-GRINDING.

There is a practical application of the modern turpentine substitute (white spirit) which it may be of interest to note. Technically it is always preferable to grind a pigment in the medium which will be used to thin it for use. This medium may be too thick or viscous to enable it to be used satisfactorily as the grinding medium. In such cases the addition

of a *little* white spirit to the grinding medium enables the latter to be used satisfactorily. If *fine grinding* is in question the heat generated by the friction on the rollers will volatilize the greater part of the spirit, and there is obtained in effect a mixture of the pigment and the original medium. Of course the cost of the spirit must be taken into account.

PART IV.

CHAPTER XII.

MIXED OR PREPARED PAINTS.

A LARGE and ever-growing part of the paint manufacturing industry consists in carrying the process of paint-grinding, which has been dealt with in Part III, a stage farther, namely in thinning or mixing the paste-paint with suitable liquid mediums in order to produce paint "ready for the brush". Several causes have contributed to the increase in the importance of this branch of the business of the modern paint manufacturer, but there are three important factors which may be mentioned. In the first place, the ordinary raw materials of the industry have increased in number and the conditions under which paints made from them are employed have changed. The pigments, oils and driers of to-day are not the same as those in general, we may almost say exclusive, use fifty years ago; and they are constantly changing. Hence even the most experienced and progressive craftsman painter is unable to keep himself fully acquainted with the industrial and scientific progress which in this as in other directions is always taking place.

In the early days of decorative painting, the craftsman painter was also the skilled paint manufacturer, if indeed by the term "paint manufacture" we can describe the more or less primitive methods carried out with a restricted range of pigments whereby the old-time painter prepared his materials. In those days there was no line of demarcation between the picture painter and the house painter. The term "painter"

implied the "artist," the man who beautified the living rooms, the religious buildings, and often the tombs of the ancients.

Not only so, but in those early days the painter or artist prepared the ground on which his decorations were applied. The most ancient examples of fresco painting known to us, as well as more recent work in tempera, abundantly prove that side by side with the actual process of applying pigmentary materials went the process or processes of preparing a suitable ground. Thus in the old-time painting methods the "plasterer" was eliminated, and the painter was always assured of a suitable ground on which to lay his colour.

Again, the painter of long ago employed a palette consisting of comparatively few pigments, and these he prepared and ground at an expenditure of care and time which would make the craftsman working under modern conditions stand aghast. In like manner he selected his vehicle—yoke of egg, wine, milk, wax, and the like. The vehicle he amalgamated with the pigment according to rules which his own experience and that of still older generations had proved to him to be the best. Then, having drawn his cartoon or pounced his design, he applied his paint.

Then by degrees came the cleavage between the picture painter and the house painter, the former confining himself more particularly to works of art, which he hoped would remain intact for the edification of future generations. To-day it must be confessed that, except in a few rare instances, the picture painter has no real technical knowledge of the pigments or vehicles which he handles, while so far as the craftsman house painter is concerned, it is to be feared that the modern methods of paint and pigment manufacture have put him completely out of touch with the technology of his materials.

It is not too much to assert therefore, that with all his experience, with all his skill and with all his best endeavours, the craftsman painter of to-day has not got it in his power

to mix paints even approximating in quality to those which his forefathers produced.

Secondly, a great revolution has taken place within recent years in the point of view from which paints are regarded, and a very clear line of demarcation has sprung up between decorative paints and protective coatings. The growth of what may be termed industrial or commercial painting has brought the latter class of materials into prominence.

Side by side with this must be noted the growth in the appreciation of the importance of the physical state or condition of the component parts of paint as affecting the durability of the paint film. We owe much in this connection to the early researches of some well-known paint experts, notably Dr. Dudley and Mr. Robert Job. It is to the latter of these that is due the credit of having carried out what was perhaps the first authentic research on the influence of the physical condition of the particles of a pigment on the durability of the paint. Nowadays every paint manufacturer is familiar with what has been termed the "law of fine grinding," and he is also cognisant of the fact that the more closely packed the pigmentary particles are in a paint film the better will the film be likely to effect its main purpose of excluding moisture and gases from without. Not less important is the "law of perfect mixing," although even to-day a thorough appreciation of the immense importance of absolutely perfect amalgamation of the pigment with its surrounding vehicle is less widespread than might be expected.

The study of paint materials from the physical side has grown in importance to an extent little dreamed of by people outside the inner circle of paint-making. It has long since been discovered that not chemical composition alone, or in many cases chiefly, influences the durability and other properties of a paint. It is now generally accepted that the physical size, conformation and arrangement of the pig-

mentary particles are of fundamental importance. Paints are, therefore, nowadays subjected not only to chemical analysis in order to prove their worth, but also to physical tests as well.

Thirdly, no consideration of the factors which have co-operated in bringing about the changes to which we have adverted would be complete without a reference to the paramount influence of public taste and opinion.

The recent vogue in water paints, in enamels and in other directions can be directly traced to the ever changing likes and dislikes of the public. Had this factor been eliminated it is probable that there would have been no such thing to-day as the highly-finished and excellent water paints and enamel paints with which everyone is familiar. Instead of water paint we should have had the old-fashioned distemper made from animal size and whiting by the painter himself, and as for enamels he would still have been struggling to obtain from whitelead and French oil varnish lustrous surfaces capable of retaining their white appearance in presence of sulphurous gases. One of the directions in which public opinion is at present manifesting itself is in the cry for hygienic, sanitary and non-poisonous paints.

Notwithstanding all the prejudiced statements and self-interested views of one party or the other, there is undoubtedly a desire on the part of the general public to be provided with paints which can reasonably be described as hygienic and harmless, both to the ultimate purchaser and to the craftsman who applies them.

The conclusions, therefore, that one necessarily arrives at are that under modern conditions the scientifically trained and practically equipped manufacturer is in the best position to manufacture paints in a form ready for the brush, and that the craftsman painter must be regarded as the expert in their application. Nothing is more futile than for a paint manufacturer to imagine that he can dictate to or instruct a qualified painter in the application of the materials

of his craft. This many manufacturers have found to their cost, and their failure was well merited. The painter cannot do without the manufacturer, and the manufacturer cannot succeed without the co-operation of the painter.

The Manufacture of Mixed Paints.—Regarded in the broadest possible way an ordinary sample of mixed paint consists of the following component parts:—

- (1) Paste-paint $\left\{ \begin{array}{l} \text{Pigment.} \\ \text{Grinding medium.} \end{array} \right.$
- (2) Thinning medium $\left\{ \begin{array}{l} \text{Oil.} \\ \text{Spirit.} \\ \text{Binder (if any).} \end{array} \right.$
- (3) Drier (may be separate or included in (2)).

The nature and proportion of each of the above-mentioned constituents will affect the properties of the mixed paint. Thus if the pigment is whitelead and the grinding medium refined linseed oil, the oil in (2) may be linseed oil, a binder is not as a rule required and the proportion of (3) will be small. If on the other hand the pigment consists of a mixture of Indian red, yellow ochre and drop black all the other constituents must be modified. The proportion of grinding medium will be much higher and ought to consist of a siccative oil; some binder will in all probability have to be included in (2) in order to reinforce the greatly increased proportion of oil in the paint and the question of drier becomes of paramount importance.

From such simple everyday illustrations we deduce the first rule of paint-making—*each stage of the operation, from the initial mixing and grinding of the pigment onwards, must be carried out with due regard to the nature of the materials which are being used and to the result which is aimed at.* Thus the consistency of the paste-paint which is about to be made into mixed paint will in many cases be different from that which would be desirable if the paste-paint were to be sold as such; and again, the fineness of

grinding will depend on whether the paste-paint is to be used in ordinary mixed paint or in enamel.

Technically there can be no doubt that the ideal method is to grind the pigment in the medium with which it will be ultimately mixed. This is particularly desirable in the case of pigments which retard drying or which absorb large proportions of oil in the process of grinding. It is obviously unpractical and unscientific to grind a pigment like Indian red or yellow ochre in raw linseed oil, and then to add an excessive quantity of "driers" to the mixed paint in order to produce a result which could have been accomplished in a more direct and efficient manner by modifying the composition of the grinding medium.

Thus we arrive at the second practical rule in paint-making—*the pigmentary part and the liquid part must be considered as separate entities, and each must be adapted to suit the properties of the other.*

But in whatever manner the initial processes are conducted we arrive ultimately at the same result, namely that a certain quantity of material in the form of a more or less stiff paste has to be mixed with a certain quantity of liquid medium. It is on the manner of this mixing that much of the success of the operation will depend and we may therefore add a third rule, namely—*the amalgamation between pigment and medium must be perfect, the theoretical condition aimed at being that each individual particle of pigment shall be surrounded by a homogeneous film of liquid medium.*

Imperfect mixing is much more common than is usually supposed, especially in cases in which the thinners are different from the medium which was used in grinding the pigment. It is evident that in such a case theoretically "perfect mixing" will not be attained until each particle of pigment is surrounded by a film of liquid consisting of a homogeneous mixture of the original grinding medium and the thinning medium.

These general considerations hold good whether the

“driers” which may have to be added to the paint are paste driers or liquid driers. If they are liquid driers they are part and parcel of the thinning medium; if they are paste driers they fall to be included in the “paste-paint,” their solid ingredients coming within the scope of pigment and their liquid constituents forming a complex grinding medium. The need for prolonged and efficient mixing in cases in which paste driers are used is imperative.

In none but the cheapest ready-mixed paints would a paint manufacturer employ the method of dumping into a mixer so much paste-paint, so much oil, so much spirit and so much paste driers. In every case in which a high-class product (such as an efficient protective paint) is in question he should design his grinding medium and his thinners in such a manner that the paste-paint already contains sufficient driers to dry the oil it contains, and that the thinners readily form a homogeneous mixture with the pigment.

The Selection of Raw Materials for Mixed Paints.—

In Part I attention has been directed to some of the points which should be attended to in the selection of raw materials. The selection of pigments which are intended to become constituents of mixed paint is in itself no inconsiderable part of the technical side of the paint manufacturer's business. Mere reading of books will not impart practical skill in this or in any other department of chemical industry. Not only are the services of a trained chemist a necessity in the modern paint works, but the specialized knowledge of the chemist must be interpreted and guided into practical and remunerative channels by the technical skill and experience of the works manager and the departmental foreman. Hence a complete survey of the composition, properties and applications of that long list of materials usually described as *paint pigments* is outside the scope of this volume. Nevertheless there are a few general principles which may be applied to the selection of all pigments whose ultimate

destination is the ready-mixed paint department, and these may be briefly epitomized.

(1) Pigments should be as finely and as uniformly ground or powdered as possible before being ground in oil. The modern tendency is all in the direction of employing pigments in a fine state of division if they are intended for use in mixed paints. This tendency is founded on sound principles. In the first place the time and power consumed in grinding in oil will be sensibly reduced *pari passu* with the increased fineness of the dry pigment. Further, the wear and tear on the grinding plant will be diminished. Again, more perfect amalgamation with the grinding medium will be ensured; and finally there will be much less risk of the pigment "settling out" from the mixed paint. A little extra care or additional cost expended on the dry pigment will, therefore, almost invariably result in tangible economies in the process of manufacture of the paint, not to speak of the enhanced intrinsic value of the product.

(2) The physical condition of the pigment should always be taken into account. Even in a material like whitelead, in connection with which many people imagine there is little room for variation in quality, surprising differences are found in the physical condition of different samples. In one case the particles are comparatively soft and easily reduced in size under the rollers, in another the texture is hard and the material assimilates much less readily with the oil. Similarly in the case of oxide of zinc, a material which presents great differences in the relative hardness of its particles. The importance of the specific gravity of pigments has already been referred to, and it is a salutary rule that every pigment whatsoever which is used in the works shall have its specific gravity determined before it is put into use. The oil-absorbing power of pigments is also important, and useful deductions can be drawn from observations as to whether the pigment and the oil hold together or whether separation occurs readily.

(3) The pigment should be perfectly dry. Water in any shape or form is one of the most fruitful sources of trouble in mixed paints and its presence should be rigorously excluded. Equal pains should be taken to ensure that moisture does not gain access through the linseed oil, turpentine or other ingredients of the mixed paint. Obviously this question of moisture is of paramount importance in the higher grade materials such as enamel paints and protective paints for iron and steel. These remarks do not refer to paints of the "emulsion" type which contain water as a necessary ingredient. Much of the art in compounding such paints lies in ensuring that the emulsion is a perfect one and that the water does not separate out.

(4) Special attention should be devoted to a careful search for *minute quantities* of deleterious ingredients. For instance, a very small percentage of silica may render an oxide of iron pigment quite unsuitable for use in a high-grade paint. Or the presence of acid may entirely destroy the value of a copperas red. Or, again, traces of basic acetate of lead in whitelead may produce unlooked-for results in the mixed paints. Particularly is careful scrutiny in this direction necessary in connection with chemical pigments such as Prussian blue and the chromes, and also in the lake pigments.

With regard to linseed oil, Chinese wood oil and other raw materials in general use in the paint-making industry, each user must apply those chemical and practical tests which intimate knowledge of his own requirements has taught him to be most instructive and reliable.

Machinery for Mixed Paints.—In principle the plant used for the amalgamation of the paste-paint and the thinners is of the simplest description, and such differences as exist are mainly in detail.

A simple form of mixer or amalgamator is shown in Fig. 60. It consists of a steel cylindrical pan with double

riveted lap jointed vertical seam, single riveted to top and bottom rings of cast iron. The vertical shaft is of steel, and the forged steel blades or beaters are set alternately on opposite sides of the shaft and can be inclined at any desired

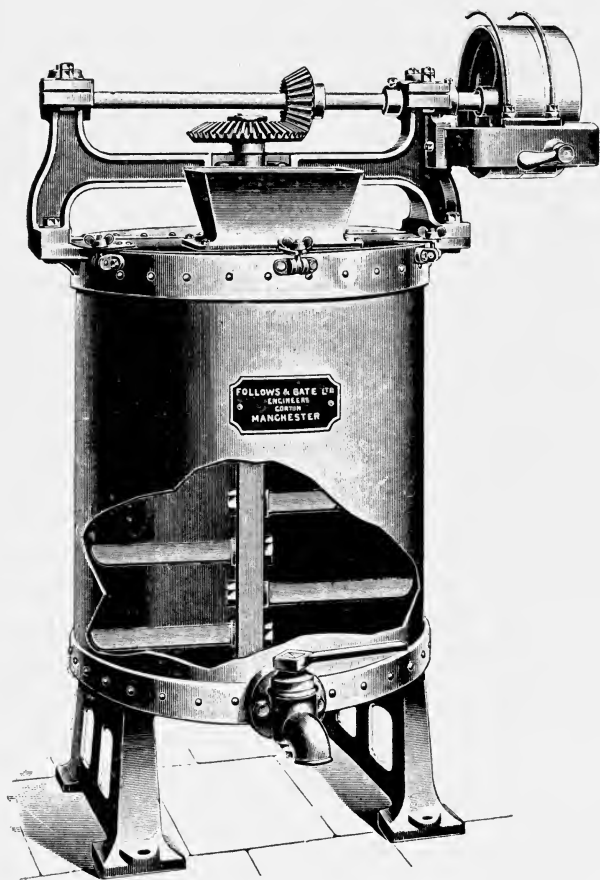


FIG. 60.—Paint mixer or amalgamator.

angle according to the consistency of the paint. The thinner the paint the more are the blades inclined. The drive is direct in the illustration, and a gang of these mixers can be operated by one drive, a clutch being fitted to each mixer

to throw it into or out of gear. The capacity of the pan may vary from 90 to 210 gallons, which is equivalent to 20 cwt. to 46 cwt. of fairly heavy paint.

The speed of the shaft of such a mixer should be 100 r.p.m. or a little more. The speed should always be adjusted to suit the nature and consistency of the paint, and a certain speed (which will vary with different materials) will be found to produce the best mixing effect. Sometimes the blades will be found to be cutting through the mass of semi-mixed paint without producing any real mixing effect. At other times the whole of the contents may be pushed or carried round *en masse*. Both these conditions involve increased cost, and may result in very inefficient mixing.

The process of charging the mixer should be carried out in a methodical manner. Unless they are specially instructed, workmen are often careless, or at any rate thoughtless, in this respect. They are sometimes inclined either to place the whole of the stiff paint in the mixer before they add any of the thinner, or to pour in all the thinner before adding any of the stiff paint. If the first course is adopted a great strain is put upon the blades, and a breakage is liable to occur. In any case the power consumed in driving the plant becomes excessive. If the other course is followed much splashing is caused, and a long time elapses before the solid and liquid portions of the charge become thoroughly incorporated.

A point which is sometimes lost sight of may be mentioned here. It is the necessity to adjust the consistency of the paste-paint to suit the conditions under which such paint will be used. If the paste is to be sold as such it is the paint-grinder's aim to produce a product which is attractive to the buyer of paste-paint. In particular he takes special pains not to produce "sloppy" paint. But paste-paint which is to be converted into mixed paint need not and indeed should not be prepared on the same lines. Provided always that effective grinding has taken place, the

consistency of the paste should be fairly soft, in order that amalgamation between the pigment and the thinners may take place as quickly and effectively as possible in the mixer.

Fig. 61 represents an amalgamator similar in construc-

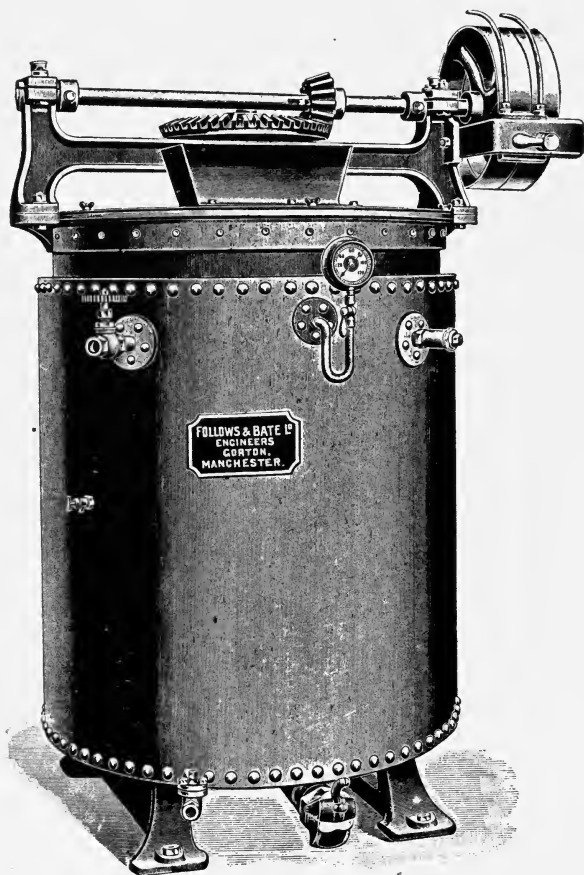


FIG. 61.—Steam jacketed paint mixer.

tion to that shown in Fig. 60 but provided with a steam jacket. This type is found useful in special cases in which the ingredients have to be mixed at temperatures above the normal.

Another type of jacketed mixer, designed by Messrs.

Torrance & Sons is shown in Fig. 62. The jacket is adapted for either steam heating or water cooling.

In Fig. 63 we see a mixer in which the mixing is brought about by the production of a rapid vortex current by means of a specially designed blade. The central spindle

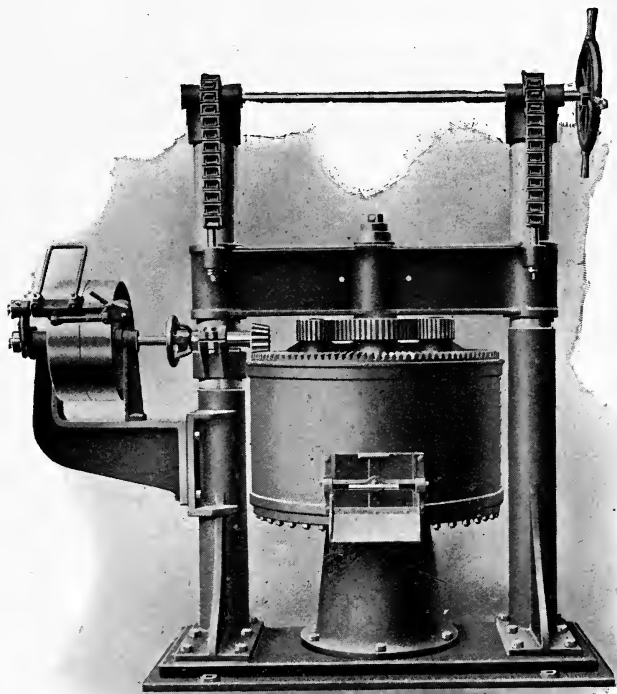


FIG. 62.—Paint mixer with jacket for water cooling or steam heating.

revolves at a very rapid rate (120 to 160 r.p.m.) and a vortex is produced which causes the material to flow down the centre of the pan and to ascend around the sides. Any tendency for the contents of the pan to move round *en masse* is prevented by a baffle plate pierced with holes fixed vertically on the side of the pan. Mixers of this type are very quick and simple in construction and a system of interchangeable pans can easily be arranged. By means of a

simple mechanical device the spindle and blade can be lifted bodily out of the pan either to allow of the latter being emptied or cleaned or to enable it to be replaced by another pan. Charges of from 60 to 100 gallons can easily be dealt with in this type of mixer.

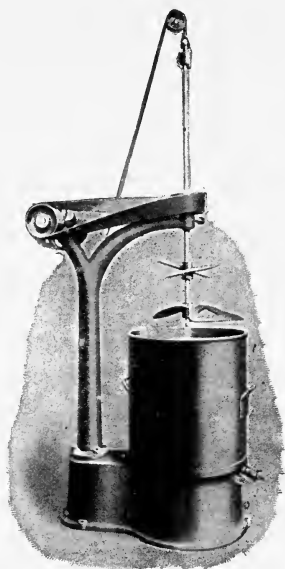


FIG. 63.—Vortex current paint mixer.

An up-to-date installation of a gang of these mixers with direct geared drive is shown in Figs. 64 and 65.

The mixers are in pairs, each pair being fixed on a central pivot. One spindle with blade attached is provided for each pair. As soon as the contents of the pan at the back (left side of illustration) are mixed, the spindle is lifted up, the pan with its contents is swung round to the opposite position (whence it discharges into the strainer fixed on the ground level) and a new charge is mixed in the other mixer.

Fig. 66 represents a mixer similar in principle to that shown in Fig. 63, but differing in the mode of driving, which instead of being by means of a belt is by direct machine-cut

bevel gearing. The beater or blade is of a specially designed "propeller" type, and when driven at a high speed produces a vortex current in the contents of the pan which induces rapid amalgamation. Too high a speed is not advisable in

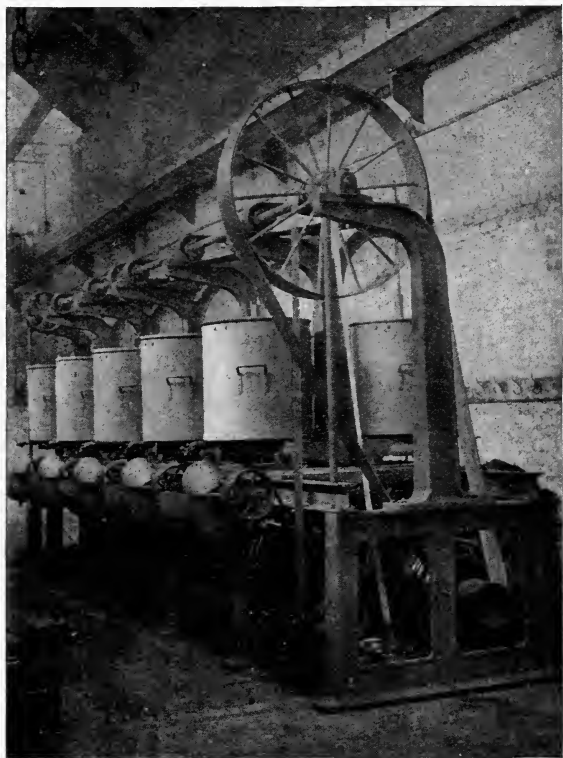


FIG. 64.—Gang of vortex current paint mixers and strainers showing driving gear.

this type, as it tends to produce rocking in the arm through which the spindle passes. On the other hand less power is consumed than is the case with the belt-driven type. The spindle can be readily withdrawn from the pan by means of the ratchet winch fixed to the side of the frame. The pan can be detached for cleaning or exchange.

Figs. 67, 68, 69 and 70, represent smaller sized mixers

than those already described. They are useful when comparatively small batches of paint have to be mixed or when quantities up to 20 gallons have to be tinted to special patterns quickly. The beaters inside the pan are detach-

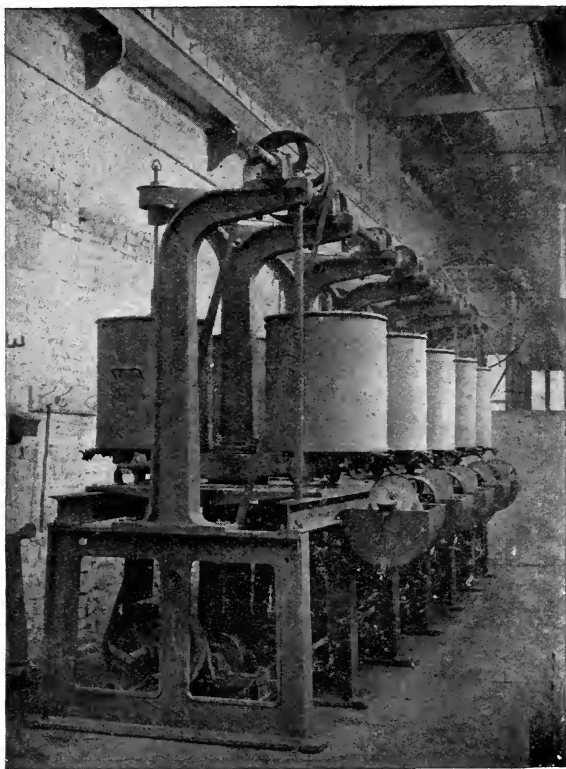


FIG. 65.—Gang of vortex current paint mixers and strainers.

able and rotate in the opposite direction to the pan itself. The addition of a baffle (shown in Fig. 70) increases the efficiency of the mixer and breaks up the whirl of the contents round the pan. The pan is detachable, and as soon as one batch of paint has been mixed and tinted another can take its place. The illustrations show the

mixer driven by a belt, but it may also be driven by a small motor mounted on the base plate of the machine.

In the case of mixers or amalgamators, as with all other



FIG. 66.—Vortex current paint mixer with direct bevel gearing.

types of paint plant, there is no such thing as a fixed or arbitrary size or design of machine which is suitable for every works or every class of manufacture. Intelligent adaptation to suit the special requirements of each case is the only plan that will give satisfaction. The engineers who manufacture paint plant are now devoting more atten-

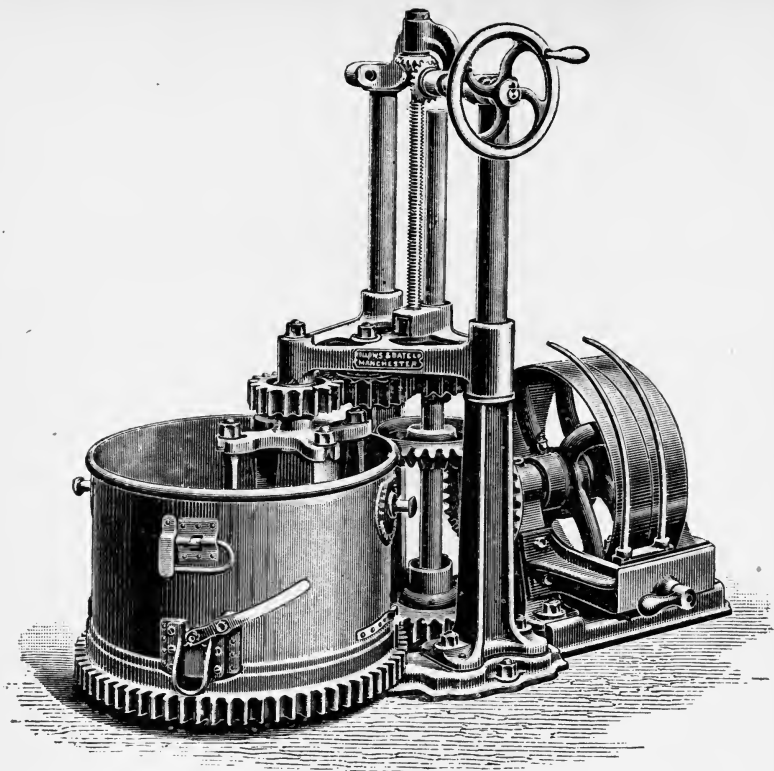


FIG. 67.

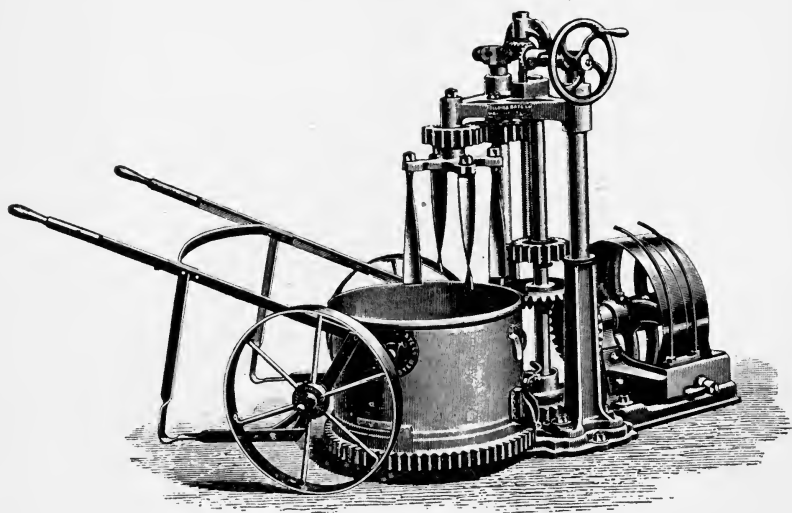


FIG. 68.

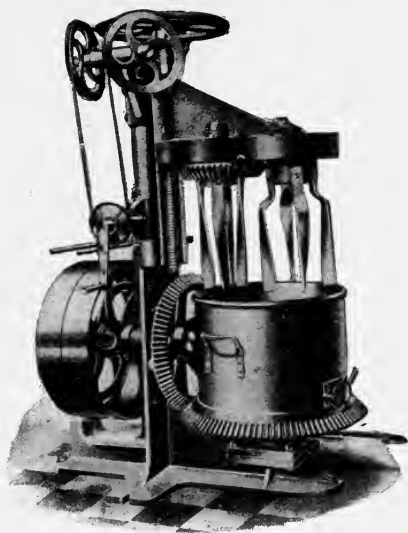


FIG. 69.

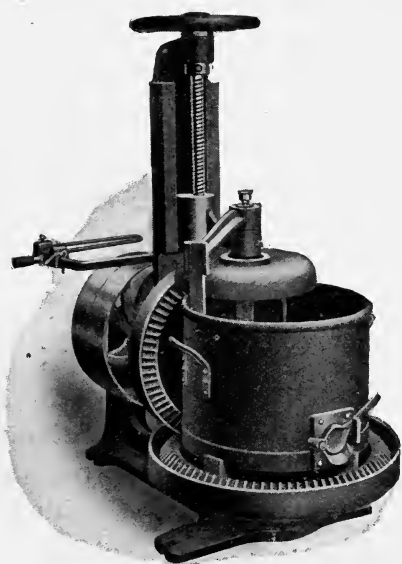


FIG. 70.

tion than formerly to the design and construction of mixing machinery, improvements in which, it must be admitted, have not progressed to the same extent during the last twenty years as in grinding plant. The growing importance of mixed paint however, has brought this matter to the front, and paint manufacturers who desire to bring their installations up to date will be well advised in considering this part of their works outfit very carefully. The great aim of the manufacturer who strives after simplicity and economy in working, is to make his manufacture a continuous process, each element of plant in the successive stage being fed by the one before it and feeding the one which follows, so that the cost of handling may be reduced as much as possible.

Tinted Paints.—This general descriptive term is often applied to paints which consist of a white base such as whitelead or oxide of zinc tinted to a varying depth of colour by the addition of suitable staining pigments. The base may be a *genuine* or so-called *pure* one, e.g. genuine white lead or genuine oxide of zinc, or it may be *reduced* by the addition of Paris white or barytes or some other reducing material or “filler” with a corresponding reduction in the cost of the paint. The following list indicates some commonly occurring tinted paints with the stainers usually employed to produce them. The decorator often prepares his own tints as he requires them from whitelead or some other white base. If a paint of great opacity be desired whitelead or lithopone will be the base selected; if “clean” delicate shades are the first consideration, then oxide of zinc will yield the best results.

List of Typical Tinted Paints.

Stone colour, stained with (according to shade required)

Yellow ochre, sienna, um-
ber.

Buff „ „ „ „ Ochre, chrome yellow,
Venetian red.

Pink priming, stained with (according to shade required)

Red lead.

Mast colour, „ „ Venetian red, chrome
yellow, burnt sienna.

Teak „ „ „ „ Venetian red, English
umber, yellow ochre.

Light slate	} colour,	,	{	Vegetable or carbon black,
Dark slate				lime or Brunswick blue.
Light lead				
Dark lead				

Chocolate colour, „ „ English umber, yellow
ochre, Venetian red, *or*
purple brown, yellow
ochre.

Tinted paints of the nature indicated above are used for two purposes. They are employed, in the first place, both in exterior and interior decoration to communicate a desired colour to a given surface. Thus the front of a house may be painted stone colour, or the walls of a room may be painted French grey. Tinted paints (and in this case the base may very well consist of lithopone) are, secondly, used as under or grounding coats. Thus if an iron railing is to be finished in an oxide red, the under coat will probably be a light terra-cotta colour; if it is to be finished in dark green, the ground may be a dark slate or dark lead colour; and a familiar shade of buff is used as the ground before oak graining. It is well for the maker of paints to make himself familiar with the probable use for which such paint is required, as he is then in a position to ensure that it possesses those properties which will enable it to perform its work satisfactorily.

CHAPTER XIII.

ENAMELS AND ENAMEL PAINTS.

THE word *enamel*, as it is understood nowadays in the paint industry, has a significance totally different from that suggested by its etymology. When we speak of an enamel in the paint trade, we usually mean a fluid or semi-fluid substance, composed essentially of an insoluble pigment base finely ground, suspended in a varnish menstruum, and capable of hardening, at ordinary temperatures, with a more or less glossy surface when applied with a brush on a suitably prepared ground. This is the painter's definition of an enamel. To the potter and ceramic artist, however, the term "enamel" conveys a different meaning. When they talk of enamels, they refer to vitreous compositions, sometimes transparent, sometimes opaque, capable of adhering by fusion to the surface of pottery or of metal. Observe that the process of fusion or smelting is at the root of the ceramic manufacturer's idea of enamel, and this connection between the words "enamel" and "smelt" takes us at once to the primary and fundamental notion expressed by the modern word enamel. The Middle-English form of the word was *en-amaile*, "amaile" being a shortened form of the Old French "esmaile," equivalent to the Italian "smalto"; and both the latter were derived from the Old High German "smalzjan"—to smelt. Thus we see that the modern decorative painter's enamel is an outcome, we may almost say an imitation, of the fused glazes and fluxes of the potter and the metal-worker.

Enamelled woodwork has become extremely fashionable in connection with interior decoration, and there is every

prospect that the demand for paints of the enamel type will continue, in connection not only with decorative work but also with surfaces which have to be protected.

Composition of Enamels.—Painters' enamels consist essentially of two parts: (1) the pigment, which may be white or coloured, and (2) the vehicle or fluid medium, which is usually composed of some specially-prepared material of the nature of varnish.

It is not, in practice, an easy matter to mix a pigment and a varnish so as to produce a material which will display the features usually associated with a first-rate enamel.

As both makers and users of enamels are aware, a hard, glossy, and smooth surface may be obtained in the first instance, which may turn soft, and in other ways display bad wearing properties. Again, while retaining a perfectly hard face, the enamel may "go off" in colour, a fault which may be due to the varnish or to the pigment, or to both. Or, again, chemical action may take place between the varnish and the pigment, with the result that the enamel shortly becomes so "tough" that a painter cannot apply it. Thus, it will be seen that the expert enamel maker has to consider many points before he can turn out an enamel capable of being used with success under ordinary working conditions.

There are four features which are usually associated with an enamel, namely (1) *extreme fineness of texture*, which implies impalpable fineness of the pigment and perfect amalgamation of the latter with the fluid medium, (2) *the capacity to dry with a high lustre and to retain that lustre* in a manner similar to a good oil varnish, (3) *the production of a hard and impermeable film*, (4) *a minimum tendency on the part of the film to change colour*.

The line of demarcation between enamels and paints is a very arbitrary one, and although the members of the two classes which are at the limit of their respective groups are quite dissimilar in composition and properties the two groups

merge imperceptibly into one another, and quite a number of materials are manufactured which may be described with equal correctness either as paints or enamels.

Perhaps the vital difference between a paint and an enamel is that in the case of paint the thinners consist essentially of linseed oil (either raw or boiled) to which drying properties and hardness are communicated by the addition *as ingredients of the paint* of driers and small quantities of oil varnish respectively. In the case of enamels, on the other hand, the thinning medium consists of a carefully designed mixture which is in effect a special form of mixing varnish and which contains *in itself* all the driers, hardening and gloss-producing materials, etc., required to produce a material exhibiting the four essential features referred to above.

The production of good enamels, then, depends on two things, first the preparation of the pigment in a state of the most perfect subdivision possible, and secondly the designing of a suitable mixing medium.

As to the preparation of the pigment the remarks which have been made on the grinding of pigments which are to be used for mixed paint in a special medium, apply with tenfold force in the grinding of pigments for enamels.

The proportion of medium used in the grinding process should be as small as possible, and should approximate as nearly as possible in composition to the medium which will be used to reduce the paste to working consistency. The finer the state of division of the pigment, the larger may the proportion of grinding medium be, because in the case of pigments which are already reduced to the practical limits of fineness the so-called grinding becomes in effect a mixing process.

All the linseed oil used in the grinding of pigments for enamel should be absolutely free from moisture, and in grinding earth colours, oxide of iron pigments and pigments which retard drying the addition of a proportion of a suit-

able siccative, gold-size or grinding japan to the grinding medium will be advisable. Such siccatives or japans must not be used haphazard and without a knowledge of their composition, otherwise serious and unexpected results may occur.

The use of "stand oil," by which general name a number of artificially thickened products of linseed oil are described, as a grinding medium is favoured by some, but it will usually be found to be inadvisable to use stand-oil in this way unless the pigment which is being ground is so fine in texture as to require no further reduction in size. In such a case the process, as has already been said, becomes one of mixing, and in this connection it may be pointed out what an efficient "mixer" the triple-roller granite mill is. If the pigment is at all gritty a viscous medium such as stand-oil should not be used as the grinding medium, because owing to the viscosity of the medium the particles of pigment are protected from the grinding action of the rollers, and the grinding process becomes unduly prolonged and very costly, and in addition gives rise to intense heat in the rollers.

In grinding pigments with viscous mediums the rollers should never be screwed up too tightly, as great friction is produced, a fact which is quickly apparent from the tremendous heat generated in the stones.

The ground paste intended for use in enamels should be transferred to the mixer or amalgamator as soon as it has left the grinding mill. It mixes better with the thinning medium when it is warm and freshly made, and that fertile source of trouble and complaint, the production of skins, is obviated. The mixing of enamel should always be carried out with strict regard to cleanliness and exactness. Every particle of dirt or dust that finds its way into the enamel at this stage will either have to be removed at a later stage or if left in the enamel will injure the latter to a greater or less extent.

Enamel Mediums.—Provided that the pigmentary con-

stituents of the enamel have been selected with due regard to the requirements as to fineness, etc., which have been referred to, by far the greater part of the skill which is essential in this branch of paint making is called for in the designing of a suitable medium. The word "designing" is used advisedly, because the modern process of making enamels and enamel paints consists essentially in *building up* a formula for the composition, each ingredient being selected for some definite reason. The technical literature on paints and pigments which has been published during the last ten years in Britain, America and France contains abundant references to such matters, and no paint-maker who professes to be an expert in his business can afford to dispense with an intimate knowledge of the various lines along which thought and research in this subject have travelled.

There are four types of thinning medium which are employed in the making of enamels and enamel paints, and these will be alluded to briefly.

(1) *The Spirit-Varnish Type*.—Thinning mediums belonging to this type may consist of a true spirit varnish in which the solvent is some volatile material (methylated spirit, wood alcohol, acetone, etc.) in which such resins as shellac, sanderac, or manila have been dissolved. Enamels made from such materials are simply *spirit-varnish paints*, and although many of the earlier attempts at enamel making were based on this method, it may be said to have sunk into unimportance except in connection with certain technical coatings for special purposes, including *retouching cycle enamels* and *enamels for electrical purposes*.

Turpentine varnishes consisting of turpentine and damar belong to the same group. Damar possesses the property of dissolving in turpentine in the cold and produces an exceedingly pale varnish which dries with a high lustre. Damar mixing varnishes therefore became very popular in the early days of enamel-making. All that required to be done was to grind oxide of zinc in refined linseed oil and to thin the

paste with a suitably compounded damar varnish, run the mixture through a cone mill, and the enamel was made. Enamels made on this principle are found not to wear well on account of the softness and brittleness of the medium. For inside use damar enamels may do fairly well, but they are not suitable for outside or for use as protective paints.

(2) *The Oil-Varnish Type*.—The objectionable features of damar enamels can be avoided by the use of a mixing medium consisting of a pale rather thin oil varnish, made from a fossil resin with a low acidity value. A number of enamels are made by mixing ground oxide of zinc in such a medium or by grinding the oxide of zinc direct in the medium and thinning with the same medium after grinding. Very tough and durable enamels can be obtained in this way but as a class they lack high lustre and finish. Great care must be exercised in the selection of the resin in the mixing varnish on account of the property possessed by many resins of “feeding-up” or “livering” when placed in contact with certain pigments. Thus kauri and manila are inadmissible in the making of mixing varnishes, but most of the true copals and animes can be used.

(3) *The Stand-oil Type*.—The discovery in England about twenty years ago that a smooth, unctuous, fine flowing enamel paint could be produced by simply mixing oxide of zinc and stand-oil together marked a new era in enamel making. Stand-oil consists of linseed oil which has been subjected to certain processes (which vary in their nature and are outside the scope of this work) with the result that it has gained enormously in viscosity. It was found that the lustre of stand-oil enamels was very great, and that the film retained its lustre and became exceedingly tough and durable. In Holland these enamels have been used for a very long time, but when they were first introduced in Britain their slow-drying properties were against them. The improvements which have taken place in the manufacture of siccatives have altered all this, and nowadays a number of manufac-

turers employ some form of stand-oil as the basis of their thinning medium.

One point should be noted, and that is that if a thick viscous medium is to be used for thinning the ground oxide of zinc the latter should be ground rather slack in a similar medium otherwise perfect amalgamation will not take place. The presence of refined linseed oil in the paste tends to reduce the lustre of the paint and certainly impedes drying.

(4) *The Compound Medium*.—This may be described as a compromise between two or more of the three before-mentioned mediums and under modern conditions it is one which is very frequently used. If we start with stand-oil and several mixing oil-varnishes containing different resins and possessing different properties as to drying, hardness, etc., we have it in our power to prepare an almost illimitable range of mixing mediums each of which will be different from the others in composition and properties. Thus the medium can be varied according as the enamel contains oxide of zinc, or oxide of zinc in association with such pigments as ochre, or sienna, or oxide of iron, or Brunswick green. It is here that the skill and experience of the enamel maker in building up his formula to suit each particular case will manifest itself. It is worthy of remark also how closely related the varnish making industry is to the manufacture of enamels; indeed, under the conditions which exist to-day the manufacturer who aims at the highest success with his enamels must make his own medium from the foundation.

Many protective paints and preparations now on the market are of the nature of enamel paints, and the foregoing remarks apply without reservation to such materials, which may be said to represent the highest technical skill of the paint manufacturer.

Enamel Paint Machinery.—The perfect and lasting finish or “face” of an enamelled surface depends very largely on whether the amalgamation of the ingredients in the enamel is perfect. Earlier in this book perfect amalgamation

has been defined as the condition when each individual particle of pigment is surrounded by an envelope of homogeneous mixing medium. In order to attain this end the medium has to be *ground into* the pigment, and even prolonged

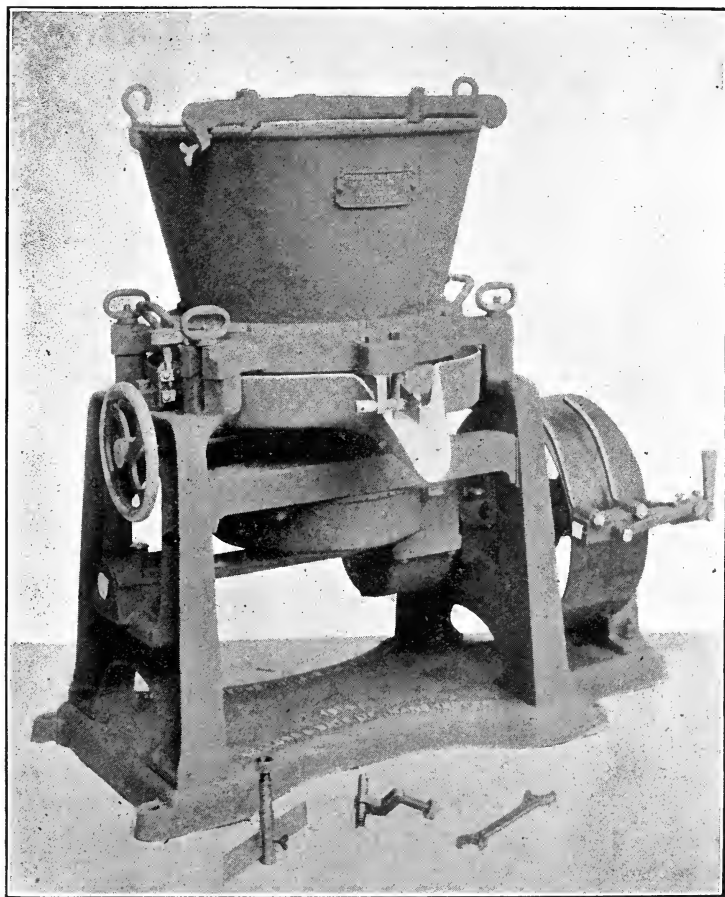


FIG. 71.—Enamel cone mill.

exposure of the enamel to the action of the beaters in a mixer or amalgamator will not effect this.

After the mixing process, therefore, in the machines de-

scribed in Chapter XII it is necessary to put the enamel through a finishing or "fining" process, which, although it is usually spoken of as grinding, is really a process of amalgamation, the viscous medium being forced into the interstices between the particles of pigment by the pressure exerted by the grinding surface of the mill.

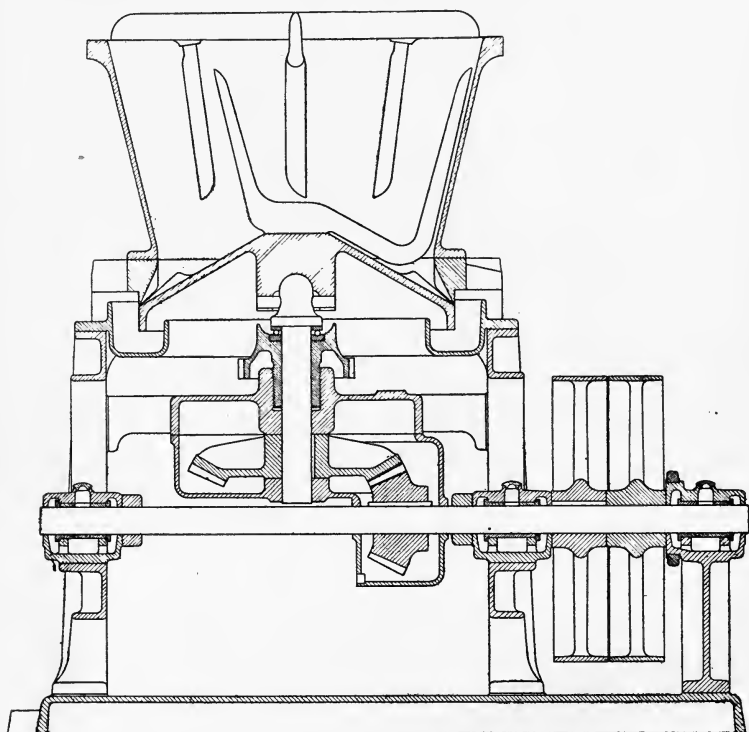


FIG. 72.—Sectional diagram of enamel cone mill.

The triple granite roller mill or the triple steel roller mill may be and is not infrequently used for this fining process, but this type of mill is not suited for dealing with liquid materials, but only for mixtures which contain a considerable proportion of pigment.

By far the greater part of the best grades of enamel is refined in cone mills. Up to the present time this type of

mill has retained its pre-eminence in enamel manufacture, but it is possible that mechanical improvements in other types of mills, and the necessity under modern conditions of

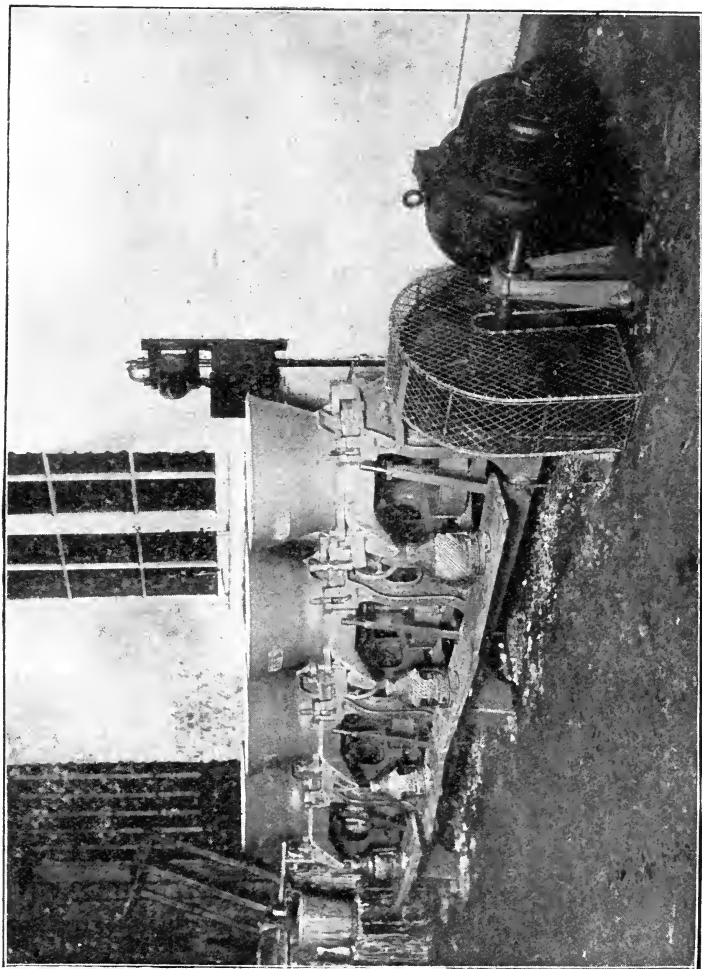


Fig. 73.—Gang of enamel cone mills with direct electric drive.

dealing quickly and effectively with enormous quantities of material, may bring competition into a realm in which the cone mill has hitherto reigned supreme. An enamel cone mill of the latest type is shown in Fig. 71 and in section in Fig. 72.

The hopper and upper grinding surface are made in two separate parts, so that when the grinding ring is completely



FIG. 74.—Gang of enamel cone mills with belt drive.

worn out a new ring can be fitted to the old hopper. This represents a considerable saving in the cost for renewals.

The bevel gearing under the cone is machine cut and runs in a totally enclosed oil bath which reduces the power

consumed, increases the life of the mill and ensures smooth running. The horizontal driving shaft is continued across the mill, and the overhanging pinion, found on the older types of cone mill and never a satisfactory mechanical arrangement, is done away with. This straight-through shaft

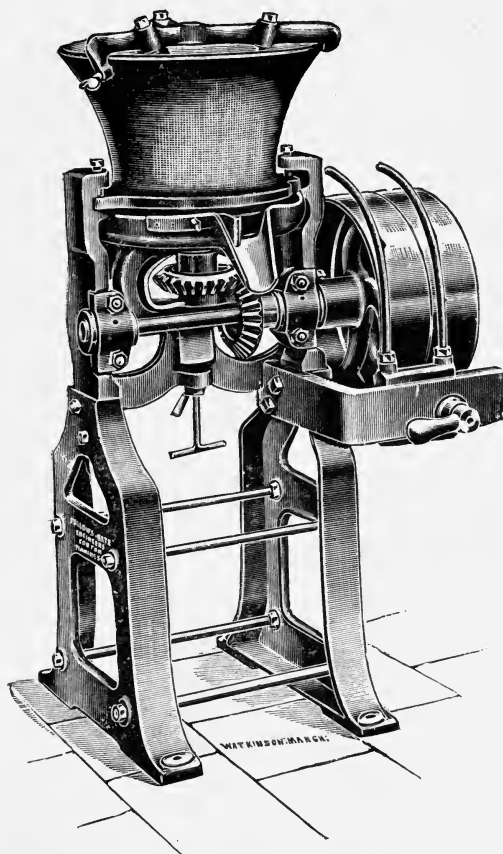


FIG. 75.—Cone mill, high type.

enables two or more mills to be coupled together, and the gang can be driven by an electric motor which should be fixed on a bed-plate which forms part of the base of the gang of mills.

An arrangement of this kind is shown in Fig. 73.

Fig. 74 illustrates another gang of small cone mills with belt drive.

Although it cannot be claimed that any mill with concentric grinding surfaces is a perfect machine mechanically the fact remains that the cone mill in its perfected form represents an exceedingly useful tool, and for the particular

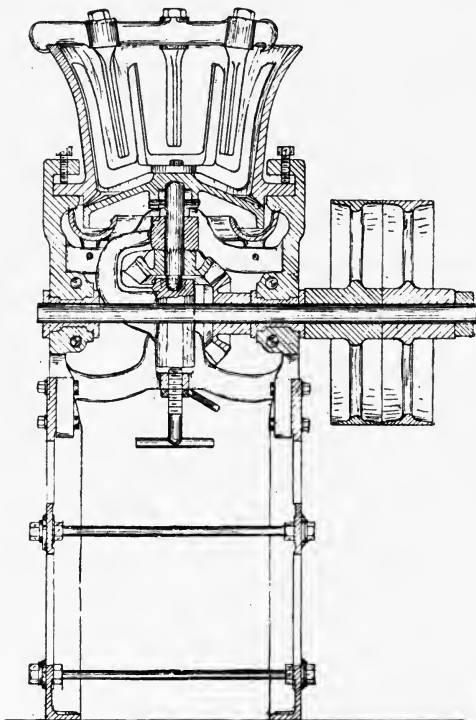


FIG. 76.—Section of cone mill, high type.

purpose we are now dealing with, the finishing of high class enamels and enamel paints, is possessed of undoubted merits. Other forms of cone mills (single and in gang) are shown in Figs. 75, 76 and 77.

A serious defect in the original cone mills was the fact that the screw by which the adjustment of the pressure was effected acted directly on the gearing below the mill. Hence

the cone could not be regulated without taking the gear off the pitch line. By a simple but ingenious arrangement this

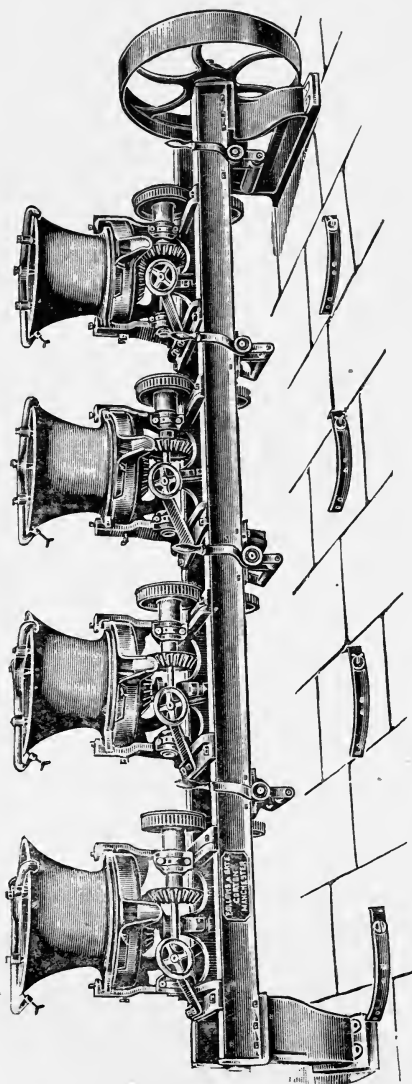


FIG. 77.—Gang of cone mills.

drawback has been remedied and the cone mill shown in Fig. 71 is fitted with this improvement.

Twelve to eighteen gallons is the capacity of the hopper in the usual standard sizes of these mills.

Mr. J. R. Torrance has pointed out that the inherent weakness from a mechanical point of view in all mills of the cone type is that the opposing surfaces are in true concentricity with each other, and he has expressed the opinion

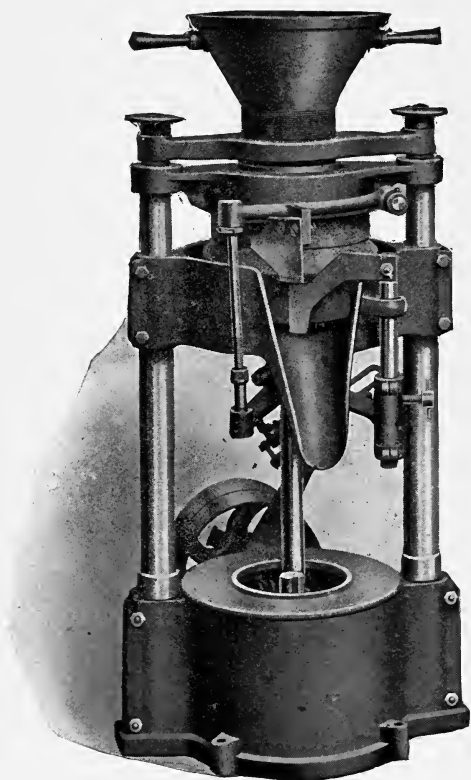


FIG. 78.—“Gyrator” mill.

that improvements are likely to be along the lines that depart from this principle. He has accordingly designed a new mill the mechanical principle in which is borrowed from the old-fashioned but effective pestle and mortar.

This mill is shown in Fig. 78. The upper grinding sur-

face corresponds to an inverted mortar, through a hole in the centre of which the material to be treated is fed. The lower and opposing grinding surface corresponds to the pestle with the ball end up and fits exactly into the hollow of the upper grinding surface. The latter is stationary but the ball revolves on its own axis, and at the same time by means of an exceedingly ingenious but effective mechanical movement it has a gyratory or "planatory" movement. Hence it does not run in true concentricity with the top stone but has a lateral as well as a circular motion.

A later and improved type of 'gyrator' mill is illustrated in Fig. 79. The whole of the top part of the mill, including the feed hopper, can be lifted by means of the balance weights. Pressure between the grinding surfaces is increased or diminished by means of the wheel-and-screw attachment at the bottom of the mill. The mill shown in the illustration is run by a direct electric drive.

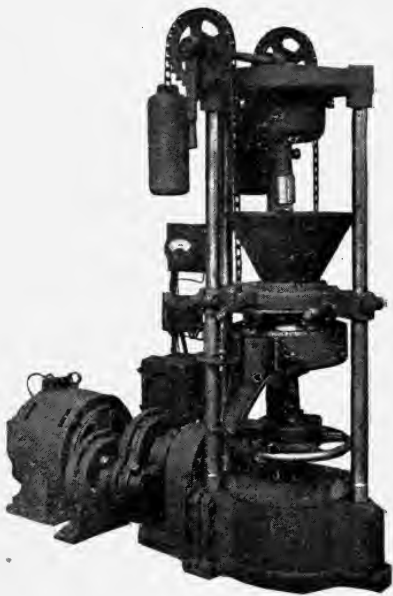


Fig. 79.—Gyrator mill with direct motor drive.

Straining or Sieving.—This is usually the last process before the enamel is run into the cans or other receptacles

in which it is packed. Many people attach undue importance to the straining of highly finished enamel paints. Strictly speaking the grinding should be so perfect that everything will pass through a sieve containing 120 meshes to the inch. Further, there is nothing to be gained by running

carefully strained enamel or paint into cans containing dust and grit. Nevertheless straining is often a necessary process especially in the case of a less highly finished article, the last stage in the manufacture of which is that of mixing in a large amalgamator.

Ordinary flat sieves quickly become choked and brush sieves are not suitable for wet materials. Fig. 80 illustrates a new strainer which is suitable for fairly viscous enamels. The strainer, which is shown with the left hand end rising above the edge of the trough, is fixed on the driving spindle in such a way that each end rises and falls alternately as the cage revolves. The contents therefore run down and across the gauze and clogging is prevented. These strainers can be fitted as an adjunct to mixers or any other finishing plant as shown in Figs. 64 and 65.

Cone mills should always be fitted with a sieve on the hopper through which the charge should be passed in order to remove pieces of grit or adventitious particles such as pieces of wood, etc., which might find their way between the grinding surfaces of the mill.

Varnish Paints.—Just as ordinary oil paints merge imperceptibly into varnish paints so do the latter merge into enamels. In general a varnish paint, while possessing a high degree of lustre and a certain amount of hardness, does not possess that fineness of texture which is associated with an enamel. It should be noted also that mere lustre of surface, which is found in varnish paints, by no means implies hardness or impermeability, properties which are usually sought for in true enamels.

Any ordinary paste-paint used by a decorator can be converted into a varnish paint by thinning it with boiled oil and a suitable oil varnish. The mixing varnishes used for paint of this class are usually of indifferent quality, and "varnish paints" as a class must be regarded as suitable only for painters' use for certain kinds of decorative work.

They cannot be classed as protective paints owing to the fact that no pains are taken to adjust the composition to suit

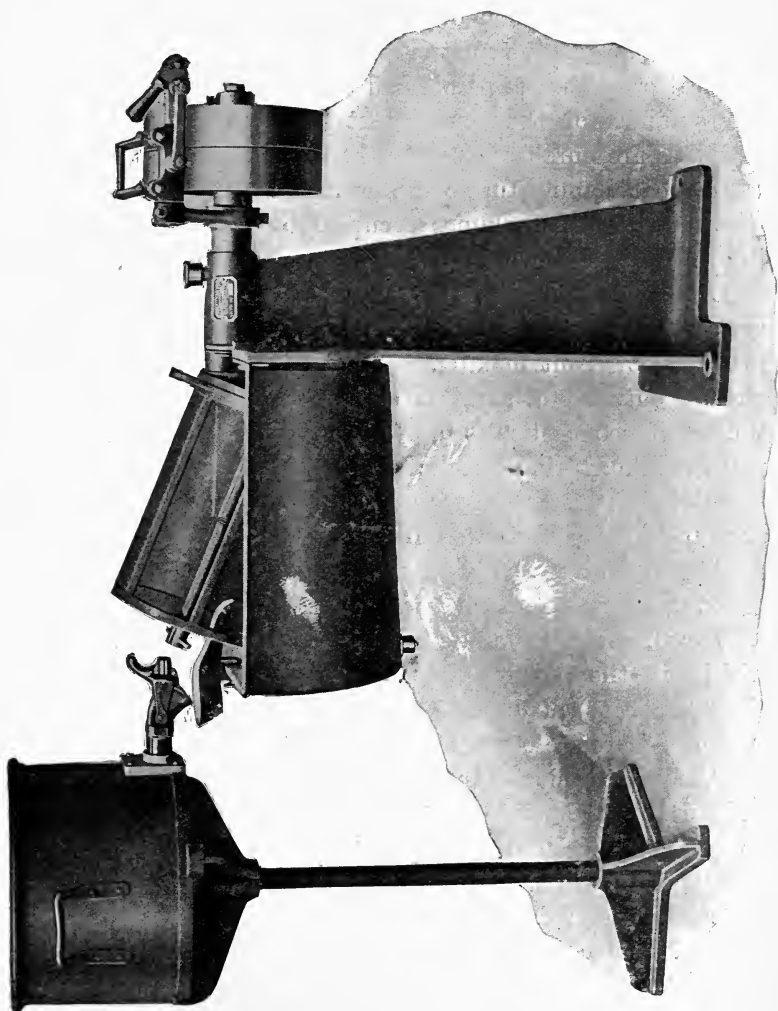


Fig. 80.—Paint or enamel strainer. (Power driven.)

given conditions. What is aimed at is merely to produce a hard glossy paint of a particular colour.

The Volume and Weight of Mixed Paints.—In all matters connected with the composition, application and sale of mixed paints and enamels there is a growing tendency to bring the conception of volume to the front, and careful consideration of the matter will prove that many of the physical properties of paints and paint films are functions of the volumes of the constituents. Hence although raw materials are purchased by weight, and weight formulas are used in the manufacture of paint materials, the paramount importance of the volumes occupied by definite weights of the ingredients and of the product cannot be overlooked.

Attention has already been directed in Chapter III., to the great importance of specific gravity in relation to the raw materials of paint making. We shall now carry the ideas already outlined a stage farther, and we shall see how the volume conception is inseparably bound up with modern paint manufacturing practice, and how a thorough understanding of the subject simplifies many problems which arise in the designing and manufacturing of mixed paints.

The unit of volume in industrial work is usually the gallon, and in the paint industry this unit is universally employed. By gallon is meant the "imperial gallon" which is the volume occupied by 10 lb. avoirdupois (70,000 grains) of distilled water at 60° F. The imperial gallon is therefore equivalent to 277.274 cubic inches.

Various "gallons" have been in use at different times and in different trades, but in the year 1689 the "wine gallon" was declared by law to contain 231 cubic inches. The "gallon" in use in America to-day is the old English wine gallon, and consequently a gallon of paint in America is 46.274 cubic inches short of the imperial gallon. It is well to bear this fact in mind not only in commercial transactions but also in dealing with figures derived from America relating to the composition of paints.

46.274 being practically one-fifth (actually .20003) of 231 we see that

120 American gallons = 100 imperial gallons

$$\text{and American gallon} = \frac{\text{Imperial gallon} \times 5}{6}$$

$$\text{and Imperial gallon} = \frac{\text{American gallon} \times 6}{5}$$

Henceforth we shall employ the term gallon as meaning imperial gallon.

Now if we know the specific gravity of a pigment or mixture of pigments all we have to do in order to find the weight of a gallon of that pigment or mixture is to multiply by 10.

Thus if the specific gravities of the pigments in three samples of paint have been found to be :—

- (1) 6.00 (whitelead),
- (2) 5.00 (oxide of zinc),
- (3) 4.12 (mixture of pigments),

the weight of a gallon of each of these pigments free from air will be 60 lb., 50 lb. and 41.2 lb. respectively.

If now a gallon of linseed oil, the specific gravity of which has been found to be .932, be added to each of these gallon weights of pigment, we obtain three mixtures of the following composition :—

- (1) 60.00 lb. whitelead
9.32 lb. linseed oil

69.32 lb. paint, measuring 2 gallons or 34.66 lb.
per gallon, i.e. possessing a specific gravity of 3.466.

- (2) 50.00 lb. oxide of zinc
9.32 lb. linseed oil

59.32 lb. paint, measuring 2 gallons or 29.66 lb.
per gallon, i.e. possessing a specific gravity of 2.966.

- (3) 41.20 lb. pigment
9.32 lb. linseed oil

50.52 lb. paint, measuring 2 gallons or 25.26 lb.
per gallon, i.e. possessing a specific gravity of 2.526.

In the case of stiff or paste-paints a perfectly simple relation exists between the weight, specific gravity and specific volume of their constituents. Thus, take a sample of ground whitelead containing 8 lb. of linseed oil to every 100 lb. of dry whitelead :—

	Weight.	Specific Gravity.	Specific Volume.
Pigment	100	6.00	16.66
Oil	8	.932	8.58
Mixture	108		25.24

The specific volume (v) is calculated from the weight (w) and the specific gravity (s) by means of the well-known physical relation

$$w = vs$$

$$\text{whence } v = \frac{w}{s}$$

$$\text{and } s = \frac{w}{v}$$

If therefore in the above illustration we divide 108 (w) by 25.24 (v) we obtain 4.28 (s) which is the specific gravity of this particular sample of ground whitelead, which will therefore weigh 42.80 lb. per gallon.

Complex mixtures can be dealt with in the same way since

$$s = \frac{v_1 s_1 + v_2 s_2 + v_3 s_3}{v_1 + v_2 + v_3}$$

That is to say, the specific gravity of a mixture is obtained by dividing the sum of the volumes of the ingredients multiplied by their respective specific gravities by the sum of the volume of the ingredients. In the case of mixtures which have been made by weight and not by volume

$$\frac{w_1}{s_1}, \frac{w_2}{s_2} \text{ and } \frac{w_3}{s_3}$$

may be written for v_1 , v_2 and v_3 .

There is, however, one important assumption made here. It is that the volume of paint is in fact the sum of the

volumes of its constituent parts. So far as admixtures of pigment and oil are concerned there is no ground to suppose that the volume of the mixture is not the sum of the volumes of the component parts always provided that amalgamation has been so perfect as to displace all the air held by the dry pigment. Experiments have proved that in the case of ordinary pigments which are insoluble in the commonly used paint mediums and which are properly amalgamated with the latter the law holds good. Nevertheless it should be noted that discrepancies will arise if solution of one ingredient in another takes place. Mixtures of linseed oil and turpentine afford no exception to the law since they mix together without contraction in volume.

We may take one more example illustrating the volume conception applied to a mixed paint:—

Weight.	Specific gravity.	Specific volume $\left(\frac{w}{s}\right)$
100 lb. oxide of zinc	5.00	20.00
10 lb. Refined linseed oil	.932	10.74
<u>110 lb.</u>		<u>30.74</u>

$$\text{specific gravity of paste} = \frac{110}{30.74} = 3.58$$

1 gallon of paste	35.8 lb.
1 gallon of thinner of specific gravity .900	9.0 lb.
produce 2 gallons of paint weighing	<u>44.8 lb.</u>
or 22.4 lb. per gallon.	

It is easy to see therefore what an aid to designing paints which have to fulfil definite requirements, such as a stated weight per gallon, the volume conception is. Provided the weights and specific gravities of the component parts are known endless changes can be rung on the volume formula, and it will be found that if general laws can be enunciated on the subject of the relative proportions of pigment and medium which should obtain in mixed paint, they have to be framed in terms of volume and not in terms of weight.

The following problem often arises :—

How many gallons (x) of a certain thinning medium whose specific gravity is s_1 must be added to each gallon of paste-paint whose specific gravity is s_2 in order to produce a mixed paint weighing N lb. per gallon?

s_1 is readily obtained by the hydrometer; s_2 is easily found by the method already indicated, and N divided by 10 gives the specific gravity of the required paint which we shall call s .

Then using the formula

$$s = \frac{v_1 s_1 + v_2 s_2}{v_1 + v_2}$$

and knowing the value of all the terms with the exception of v_1 , and writing x for v_1 ,

we have

$$s = \frac{x s_1 + s_2}{x + 1};$$

and solving x

we find

$$x = \frac{s_2 - s}{s - s_1}.$$

Thus, supposing the specific gravity of the paste-paint is 4.2, that of the thinners .950, and the mixed paint is required to weigh 18 lb. per gallon,

$$\text{then } x = \frac{4.20 - 1.80}{1.80 - .95} = \frac{2.40}{.85} = 2.82.$$

That is to say, 2.82 gallons of the thinning medium must be added to each gallon of the paste-paint referred to in order to produce a mixed paint which will weigh 18 lbs. per gallon.

Unnecessary complexity is often introduced into the costing of mixed paints and enamels through the quantities of materials used in the manufacture being expressed partly by weight and partly by volume. The simplest and most accurate method is to express everything by weight (since the goods are purchased by weight) and to put against each item its specific gravity. If this is done with each item

from the prime raw materials onwards no elaborate calculations are required if a slight change in the "mixing" is desired, as, for example, if the weight of the mixed paint is to be increased or decreased one lb. per gallon. Thus, if in the above mentioned calculation we wish the resulting paint to weigh 16 lb. per gallon, we simply write

$$x = \frac{4.20 - 1.60}{1.60 - .95} = 4.$$

The Volume of Paint Films.—The question whether paint alters in volume after it has been applied on a surface and has become converted into a dry film has never been accurately determined. Such experiments as have been made tend to show that if the paint be applied to a smooth impervious surface such as glass, no material change in volume takes place in the case of paints containing fair proportions of linseed oil, the reduction in bulk caused by the evaporation of the volatile constituents being balanced by the absorption of oxygen by the oil. Under the ordinary conditions of painting, however, other factors must be taken into account, and chief among these is the absorption of a portion of the liquid constituents by the surface beneath.

The question of "spreading power" is so important from a practical point of view that it has frequently to be determined, and in such cases the volume of paint used on a given area and the thickness of the paint film which is produced are matters which possess more than a mere academic interest.

If we assume, as we appear to be reasonably justified in doing, that no material change in volume takes place in the drying of a paint film the average thickness of the film can be calculated from the spreading power of the paint. Suppose that a gallon of paint is spread over 100 square yards, then knowing that a gallon contains 277.274 cubic inches, we can regard the latter figure as the product of the length and the breadth and the thickness of the film.

In this particular case therefore the average thickness of the film will be

$$= \frac{277 \cdot 274}{100 \times 36 \times 36} = \cdot 00214 \text{ inch,}$$

and in general the average thickness of a film expressed in inches will be found by dividing the factor $\cdot 214$ by the number of square yards over which one gallon of the paint can be spread.

By multiplying the figure expressing the thickness in terms of inches by 28.175 we obtain the thickness in millimetres. As a rule paint films vary in thickness from $\frac{1}{500}$ th to $\frac{1}{200}$ th part of an inch.

PART V.

CHAPTER XIV.

MODERN CONDITIONS WHICH AFFECT THE SELECTION AND APPLICATION OF PAINT.

THE original use of paint was probably for decoration only. The words "paint," "pigment" and "picture" are all traceable to the same origin, a root—"pig" or "pic"—which manifests itself in the Latin "pictus," "pingere" and "pigmentum," and in the allied Sanscrit word "pinj" (to dye or colour). Ancient painting work therefore, whether in monochrome or polychrome, was of the nature of ornamentation, although one has only to examine such portions of fresco and tempera painting as have been preserved to be struck with admiration and amazement at the knowledge and manipulative skill that enabled the decorative artists of those bygone days to execute such indestructible works of art.

A great deal of ancient colouring or painting, however, consisted in simply daubing or smearing either dry colour, such as red or yellow ochre, or these pigments mixed with water, over the surface under treatment. A time at length came when through the progress of civilization, especially industrial and commercial civilization, it became necessary to protect the outer surface of structures from the destructive effects of moisture, salt water, the atmosphere and the like, as well as from noxious gases and vapours which the rise of towns and the development of the manufacturing arts generate. This opened a new field for paints, namely, their employment as protective agents.

It is obvious that if a paint is required simply and solely as a decorative agent for application to an ordinary surface under normal conditions, much more latitude is permissible in the selection of the article than if the paint is to be employed with the specific object of protecting a given surface from certain external agencies of a presumably destructive nature.

So far as ordinary decorative paints are concerned, if the principles governing paint-grinding are correctly followed, and the necessary limitations as regards the blending of pigments of varying composition are observed, the paint manufacturer has performed all that he is, in ordinary circumstances, in a position to undertake.

On the other hand, with paints which are to be used as protective agents, the case is somewhat different. We may justly ask—Is it not the maker of the paint, with his expert knowledge of the properties of the article and of the probable or certain effects upon it of such agents as heat, moisture, sundry chemicals and the like, who ought to consider and advise in a scientific and trustworthy manner as to the best means whereby a given result may be obtained?

The golden rule for success in this direction on the manufacturer's part is *experiment*—abundance of accurate and painstaking experiment. To enable results to be correctly deduced from evidence based on experiment it is essential that strict scientific method be observed in the conduct of the investigation. A mass of results carelessly arrived at is only confusing, and leads to nothing. No pains should be spared to ensure that all the external conditions under which different pigments or paints are being tested are uniform, otherwise the results will be valueless.

Let us suppose that it is desired to compare the efficacy of two or more samples of paint for protecting ironwork under definite climatic conditions. In order to arrive at comparable results the several paints must be applied in identically the same manner on precisely similar pieces of

iron, which must thereafter be exposed to the same external agencies for the same length of time.

For example, if the painted iron plates are suspended in perfectly dry air, results will be arrived at which will differ from those which will be obtained if the plates are kept under water. Again, from the results in dry air one could not predict with certainty what would occur in moist air. Further, if the iron plates are replaced by wooden panels, entirely divergent results will in all probability be obtained. In short, in selecting or recommending a paint for some special purpose, the actual conditions of the case should be ascertained and provided for.

Ironwork is porous, and, unless it is coated with a protective medium while still hot, moisture and air will be absorbed, and hence when it is painted afterwards all the elements of corrosion are present below the skin of paint. Many iron and steel structures which appear to the casual observer to be coated with a continuous and well preserved skin of paint will be found on close examination to present signs of serious corrosion underneath the paint film. The longer a paint film remains impervious to moisture from without the longer it may be expected under ordinary conditions to protect the surface beneath.

A true anti-corrosive priming paint plays an important mechanical part in closing the pores of the metal so that moisture cannot be absorbed or gases occluded.

For wood surfaces linseed oil paints are probably the best except in abnormal cases, but for metallic surfaces the use of linseed oil is open to objection. A film of linseed oil or of paint containing linseed oil sooner or later becomes porous owing to the progressive oxidation of the oil. Great advances in paint technology have been made in the direction of designing mediums which are less liable than linseed oil to this defect or which contain ingredients which reinforce the linseed oil.

A metallic surface is sometimes spoken of as *non-absorbent*—non-absorbent, that is, of paint or anti-corrosive compositions. Films of these substances will lie on the surface and will not, to the same extent as in the case of wood, permeate a thin layer of the body which has been coated with them. At the same time the *porosity*, or capacity for absorbing oxygen and moisture, of a metallic surface such as cast iron or steel should not be lost sight of.

There can be no doubt that electrolytic action plays a large part in the corrosion of ironwork. This may be caused by inequalities in the texture or composition of the metal, or by different metals in contact. Thus cast iron and wrought iron will form a galvanic "couple". Care should be exercised that the pigment selected as the base of the protective paint does not itself set up this action. It has been asserted that the presence of moisture is necessary for corrosion under the paint film to proceed, the theory being that the action is one of electrolysis. Without entering into a discussion on this point we may safely say that the absence of moisture beneath or in the paint materially reduces the risk of corrosion.

The persistent vibration of structures such as bridges and the like is a fertile source of decay in protective paints. The alternate expansion and contraction which the film suffers rapidly destroy the continuity and impermeability of its surface, and the active producer of corrosion, moisture, effects an entrance. Hence not only must extreme toughness and impermeability be communicated to a protective paint which lays claim to efficiency in service, but it must be elastic as well.

The necessity under modern conditions of applying paint to comparatively new lime plaster as well as to the so-called patent and quick-setting plasters (many of which are heavily loaded with chemical matter) and to cement has introduced an entirely new set of requirements in connection with paints which are to be used on such surfaces. The aim which the

scientific paint maker of to-day has before him is the production of a non-saponifiable, moisture-resisting paint. Although no one has been quite bold enough to claim that he has produced such an article yet, great advances have been made in this direction chiefly through the agency of tung oil, the nature and treatment of which is becoming better understood by the progressive and scientifically-guided manufacturer.

The user of paints must state his requirements intelligently, and if he does so he has at command a variety of articles each of which is suitable for a particular purpose. The days of the patent-pill paint are gone !

CHAPTER XV.

THE DESIGNING, TESTING AND MATCHING OF PAINTS.

THE idea contained in the expression "designing of paints" is one which is novel to many people. And yet it is a logical result from a proper appreciation of the points which have been laid stress on throughout this volume, and particularly these touched on very briefly in the preceding chapter.

A paint is regarded nowadays as a specialized product which is intended for use in a particular manner on a particular surface or class of surfaces, and which may reasonably be expected to produce certain results and withstand certain destructive agencies.

Here is a wall, says the paint manufacturer, typical of many similar walls all of which must be painted. It consists of a quick-setting plaster finished with a hard almost impervious face. It contains alkaline matter and moisture, and neither of these can escape readily owing to the hard face. Four coats of paint have to be applied to this wall, and the last coat must be of the nature of a lustrous enamel. Then he begins to design or build up a formula for the paint required for each of the four coats. As to the first coat, he knows that the surface lacks "key," is hard, damp and alkaline, and that whatever is used as the first coat must not only adhere to the surface and provide a hold or "key" for the second coat but must also be sufficiently impervious to hold back to as great an extent as possible the moisture and alkali in the wall. So he proceeds with each coat, first diagnosing the facts with which he has to deal and then applying his specialized technical knowledge to pre-

paring a mixture which will most effectively meet the circumstances.

Or, to take another example, a steel structure has to be painted. It has never been painted before, but the steel work has been coated at the steel works with one of those abominations which pass for paint in the opinion of some, and are known variously as "shop-coat," "foundry paint" and "slap-dash"—the latter being a peculiarly appropriate designation. Three coats of protective paint have to be applied. The paint manufacturer will of course in the first instance endeavour to secure that the surface is cleaned in such a manner as to render it fit to receive paint, and he will then design or build up the formulæ for the first, second and third coats on the basis of what he finds to be the conditions to which the structure will be exposed. The first coat will probably be of the nature of a "filler" and will be free from any ingredients likely to induce corrosion. It will probably also be fairly quick drying and impervious in character in order to prevent moisture gaining access to the metal beneath before the second coat is applied. Finally, the last coat will be designed to resist the particular destructive influences to which the building in question will be exposed.

Thus we see that the idea of designing and building up the formula is inseparable from the modern conception of specialized paint manufacture.

The remarks made in Chapter III. with regard to the testing of raw material may be applied to the testing of paint also. Although it is necessary from time to time to undertake an exact and carefully conducted chemical analysis of a given sample of paint, such an examination is not always necessary or indeed practicable. We may assume that in an average paint factory it is necessary very frequently, perhaps daily, to form an opinion as to the quality, value and cost of various samples of paint, and that fre-

quently the time at disposal for arriving at these determinations is extremely limited. Obviously therefore a detailed analytical examination is often out of the question, but often though by no means invariably the exercise of skill and judgment is all that is necessary to arrive at a sufficiently exact appreciation of the desired particulars. For this purpose it is necessary to have at hand and ready for immediate reference a set of carefully prepared standard samples of various paints, and especially paste-paints, the composition of each of which is known. The use of such standard samples, when a sample of paint has to be matched within, it may be, a few minutes, will commend itself to everyone who has had occasion to face the problem. Many cases present themselves, however, in which the only satisfactory plan is to carry out a chemical examination. The following paragraphs which refer to commonly occurring paints contain suggestions which experience has proved to be serviceable for expeditious examination. Analytical and chemical details are omitted, as numerous handbooks on this branch of the subject exist, and it is presumed that the services of a qualified chemist are available. It should be noted also that the following notes have reference more particularly to the usual commercial forms of paste-paints. In the case of mixed paints more elaborate methods are necessary.

White Pastes.—A qualitative test will speedily demonstrate whether the base is lead or zinc. If whitelead is the base, the best method is to proceed at once to determine quantitatively the proportion in which it is present, a process which can in the great majority of cases be accomplished with both ease and expedition from the circumstance that the only probable diluent is barium sulphate. If lead proves to be absent and zinc is found, the question arises as to the form in which the latter is present—whether as oxide or sulphide, or as a mixture of the two. The great opacity and excellent paint-forming pro-

perties of sulphide of zinc in its pigmentary form of "lithopone," combined with its low price as compared with oxide of zinc, have caused this substance to become an important constituent of many "zinc paints," and therefore its presence should always be sought for. We should bear in mind that paint composed of nothing but lithopone and oil will prove on analysis to contain sulphate of barium in proportions varying with the grade of pigment used—usually from 70 to 75 per cent, the sulphate of barium in this case being an essential part of the lithopone. In the case of a compound paint, therefore, consisting of oxide of zinc, lithopone and added barytes, the services of a skilled paint expert are required in order that the results of analysis may be correctly interpreted.

When a sample of "white paint" is submitted which is evidently of poor quality, and which has to be matched at a given price, it is convenient to have at hand a series of samples containing whitelead and lithopone respectively reduced with barytes in known proportions, say 50, 40, 30, 20 and 10 per cent. The cost of materials in these various blends being known, there is usually no difficulty in selecting one of them that approximates closely in general appearance and properties to the sample under examination.

Pastes containing Oxide of Iron.—When paste-paints the foundation of which is oxide of iron have to be matched, they are usually assayed on the basis of colour and staining power. It is well to compare the latter property first, and here a range of samples of known strength will prove useful. When a standard sample of suitable strength has been selected to match the sample under examination, the addition of small quantities of strong tinting oxides frequently suffices to bring about a correct match.

It is not uncommon for oxide of iron paste-paints to have to conform to stringent specification as regards the percentage of ferric oxide, etc. When this is the case, the

composition of the pigments used to effect the match must of course be accurately known. (See also Chap. VII.)

Paste Stainers.—In these staining power is of special importance. Colour also should be attended to, not only in relation to the paste as it stands, but also when the latter is added to a large excess of whitelead. Two samples of burnt umber in oil, for example, may match well in the pure state, but may produce altogether different shades when reduced in the same proportions with whitelead. Opacity, which is a feature which cannot be dispensed with in paints that are to be used as self-colours, is not of paramount importance in this group; indeed some of the finest and most useful stainers are the most transparent. (See also Chap. VI.)

Paste Blacks.—It is only after some experience in matching so-called “black paints” that one appreciates the variety of shades that pass for black. In many works the black paint pug is the convenient receptacle in which all the refuse and spoiled batches of paint in all colours are worked off. This of course is not as it should be, and the practice does not prevail in well-regulated establishments. Admittedly, there is frequently some little difficulty in hitting off the exact colour of a sample of black paint, and at the same time preserving opacity and staining power. Drop black, carbon black, lamp black and Prussian or Brunswick blue comprise the list of staining pigments which may be expected to find a place, singly or together, in an average sample of good black paint. Associated with them there will in all probability be varying proportions of barytes and of whiting. Some recipes for black paste-paint contain whitelead, and specifications are in everyday use among engineers that provide for a considerable percentage of this pigment. Paints compounded on this principle are of course not black, but grey.

Chemical and Fine Colours in Paste Form.—Such materials as these (containing chrome yellow, Prussian blue, Brunswick green, the lakes, etc.), are mainly used for decorative purposes, either as self-colours or as stainers, to impart a portion of their characteristic hue to a base such as whitelead or oxide of zinc. Hence the colour of such pastes, both in their pure and in a reduced state, is a prime factor in matching samples. It is important to remember how great an influence the reducing agent exerts on the colour of the reduced paint. Thus whitelead, oxide of zinc, whiting, sulphate of barium and terra-alba, produce different shades when employed to reduce, say, lemon chrome or crimson lake. Some pigments, such as oxide of zinc and in a less degree terra-alba, tend to preserve the brilliancy of the undiluted pigments unimpaired; others, such as whitelead and whiting, have the effect of reducing the brilliancy to a greater or less extent.

Oil Absorbed in Grinding Pigments.—It is necessary in dealing with the subject of matching paste-paints to refer to the influence exerted by the oil or other fluid medium contained in the paste. Evidently, if a comparison in regard to staining power is instituted between two samples of paste, a variation in the consistency of the two samples will introduce a palpable error into the determination, for the simple reason that although equal weights of *paint* are being examined these do not contain equal weights of *pigment*. In stating results of comparative tests for staining power between different samples of paste, it becomes necessary in many cases to make allowance for divergences in the proportion of oil contained in the several samples. Again, it is frequently of the greatest importance to be able to estimate approximately the proportion of oil that will be required in the grinding of a paste which contains a blend of pigments. The oil is usually an important item when the question of cost comes to be considered, and

it is unfortunate for the paint-grinder if he finds that 18 per cent of oil is required to produce a particular paste when he has estimated that 12 per cent will suffice. The simplest and most accurate method of making such estimates is to determine accurately under the actual conditions of paint grinding the percentage of oil required by every standard grade of pigment in the paint-works. If these figures are known, a simple calculation suffices to determine the proportion of oil required by any possible combination of dry pigment in order to convert it into paste form.

It will be convenient to recapitulate, at this point, the percentage proportions of grinding medium in the form of refined, raw or boiled linseed oil (or mixtures of these as indicated in Chapters V. to IX.) which may be regarded as normally required in reducing typical samples of ordinary pigments to the form of paste. Some confusion is liable to occur in stating percentages of oil unless it is clearly stated whether the percentage relates to the oil contained in the paste or the oil which one hundred parts of the pigment will require in order to convert it into a paste of normal consistency.

The figures given in the following table represent the number of parts by weight of oil required by 100 parts by weight of the respective dry pigments.

Whitelead (English stack-made)	. . .	$6\frac{1}{4}$ to 7
„ (chamber process)	. . .	$7\frac{1}{2}$ to 8
Barytes (best white)	. . .	7
„ 2nd „	. . .	8
„ (common grey)	. . .	10
Oxide of zinc	. . .	10 to 12
Lithopone	. . .	10
Sulphate of lead	} . . .	8
Basic sulphate of lead		
Whiting	} . . .	23
Paris white		
Oxide of iron pigments	. . .	18 to 22
Grinding ochre (French and English)	. . .	25 to 40

Italian ochre	87
Raw sienna	90 to 128
Burnt sienna	85 to 104
Raw Turkey umber	66
Burnt Turkey umber	85
Bone black (drop black)	60 to 80
Lamp black	90
Vegetable black }	100 to 110
Carbon black }	
Lead chromes (genuine)	12 to 16
Ultramarine	30 to 37
Lime blue	25 to 30
Prussian blue	100
Brunswick blue	14
Celestial blue	10 to 12
Brunswick green	15 to 20
Vandyke brown	100

The practical utility of being in a position to estimate with approximate accuracy the proportion of oil which will be required in the grinding of any given mixture of dry pigments will be appreciated by every one conversant with the routine of paint-making. Approximations or estimates of this kind are frequently necessary in quoting to specification, in matching samples, and in the preparation of materials at a given limit of cost.

When hand-made samples of paint are being made up it is well to work with as large a unit of weight as possible. The pound unit is usually too large, unless the constituents of the paint are few in number and are present in equal, or nearly equal, proportions. In the case of a tinted paint containing comparatively small quantities of stainers, the adoption of a pound unit would result in the production of a sample too bulky for experimental purposes. In cases in which the metric system of weights and measures cannot be adopted a convenient unit is that of 1 oz., which is specially suitable, not only on account of its workable size, but also

on account of the simple relations in which ounces, pounds, and hundredweights stand to one another, in the event of the ounce mixing having to be converted into a hundredweight one. For if every pound in the experimental mixing to be taken as representing 1 cwt. in working weight, then every ounce will represent 7 lb. Thus :—

	Experimental Weights.		Calculated Working Weights.		
	lb.	oz.	cwt.	qr.	lb.
Whitelead . . .	2	2	2	0	14
Carbon black . . .	0	1	0	0	7
Lime blue . . .	0	4	0	1	0
Linseed oil . . .	0	5	0	1	7

In grinding lead-colour paint in bulk in accordance with the above formula, the probability is that the proportion of oil given will be found to be excessive, because inspection of the working weights suggest that, on the basis of the figures given in the table of pigments, not more than 33 lb. of oil would be required in the above mixing. This figure is arrived at thus :—

	Pigments.				Oil. lb.
	cwts.	qrs.	lb.		
Whitelead	2	0	14 at	8 per cent.	19
Carbon black	0	0	7 at	100 per cent.	7
Lime blue	0	1	0 at	25 per cent.	7
Total					<u>33 lb.</u>

THE PROCESS OF MATCHING A SAMPLE OF PAINT.

As a rule two distinct processes are implied when the expression “matching a paint” is used. In the first place the component parts of the sample which is being matched have to be determined; and secondly, by the aid of the information so acquired a new sample has to be built up

possessing the same or similar properties as the original and capable of being produced at a definite limit of cost. These two processes may be referred to as the *analysis* and the *synthesis* of the sample respectively.

A discussion of the chemical analysis of paints is outside the scope of this manual, and there are several treatises which deal specifically with this side of the subject, while much valuable information will be found scattered through the technical literature of the last ten years.

The complexity and difficulty which surround the analysis of paints are due in a great measure to the numerous possible combinations in which the chemical compounds which compose the pigments may be present, and matters are complicated by the highly complex nature of many of the modern paint mediums. In order to give a useful report, therefore, the analyst must be something of a paint technologist. In any case he will have abundant opportunities for the exercise of ingenuity in devising methods of analysis to suit particular cases and for practical skill in carrying them out.

THE PHYSICAL TESTING OF PAINTS.

It is recognised nowadays that the technical value of a paint depends very largely on its physical condition, and hence an examination of the physical properties of a paint is necessary in order to enable an opinion to be formed as to whether the paint is likely to fulfil the service required of it.

The physical condition of a mixed paint (usually described as the "consistency" of the paint) is determined not only by the relative proportions in which pigment and medium are present, but also by the nature of the solid and liquid constituents respectively. There is no very satisfactory term by which to indicate that collection of properties whereby is determined the thickness of the film which will be produced when a paint is applied by means of a brush on a given surface. A trained painter knows fairly accu-

ately by experience how much paint should be applied, and what he endeavours to obtain in his hand-mixed paint is such a consistency or viscosity or fluidity (none of the terms are satisfactory) as will enable him to lay this standard quantity on a surface with the best results. The practical testing of paints under the brush is a department of physical testing which is neglected by many manufacturers, but it is extremely important. In such matters the personal element counts for much, and there are good grounds for believing that even among trained painters themselves there is no fixed standard of consistency in paints.

In order to eliminate the personal element as much as possible and to express the consistency of paint in terms of recognizable standards attempts have been made to adopt a mechanical system of testing the physical property or assemblage of properties commonly known as viscosity. Although the term viscosity is open to objection on academic grounds when it is used as a synonym for consistency, it is a convenient expression and has the advantage of suggesting in a wide and general way that it is the flowing properties of a fluid or semifluid material that are in question. It is well to bear in mind, however, that the "viscosities" of paints expressed in figures are liable to be exceedingly misleading and may bear little relation to the working properties of the paints under the brush, or to the durability of the paint in service. Nevertheless, as some sort of physical measurement is advantageous, attention may be directed to the suitability of the "Stormer Viscosimeter" for carrying out measurements of the viscosities of paints.

The principle of this viscosimeter is that of measuring the resistance offered to the rotation of a cylinder immersed in the liquid under examination. The apparatus consists essentially of a test cup in which is placed the liquid the viscosity of which is to be tested, a bath or jacket in which the test cup is placed and which is maintained at a constant temperature by means of water or oil, and a cylinder

attached to a spindle, which by means of a mechanical arrangement rotates within the test cup by the falling of a weight.

The temperature which is usually adopted as the standard in testing paints and varnishes is 20° C., and a liquid which it has been found convenient to adopt as the standard in viscosity determinations is glycerine of 95 per cent strength, so adjusted that at 20° C. the index point on the graduated dial of the machine makes one complete revolution in 2 minutes. By adding weights to the string which is attached to the gearing of the spindle the speed of rotation of the cylinder can be altered, and the weight required to rotate the cylinder a given number of times in a unit period is a measure of the viscosity.

The index of viscosity may be defined as the force (or weight) required to produce a given shear in a given time. If therefore we adopt a minute as the unit of time, a gram as the unit of weight and the shear (weight on the string) produced by 100 revolutions of the cylinder as the unit shear, then the viscosity may be expressed as the number of grams required to cause the cylinder to revolve 100 times in one minute. From every result obtained in this way, it is necessary to deduct the weight required to set the cylinder in motion when running free in air, that is to say the equivalent of the friction of the machine. This usually amounts to 5 grams. (See "Journal of Industrial and Engineering Chemistry," 1911, p. 737).

Tests for Fineness of Grinding.—Since a paint containing finely ground pigment possesses greater opacity and tinctorial power, and will also cover a greater area, than a paint whose particles are less finely divided, it is important to be able to determine the relative fineness of different samples of ground paint in a prompt and reliable manner. Notwithstanding the fact that the fineness of a sample of paint is in many cases the ultimate criterion of its useful-

ness for a particular purpose, the tests to which paint is put in order that this property may be determined are often of an exceedingly crude nature. By rubbing a portion of the paint between the thumb-nails or with a palette-knife on a sheet of glass, some idea can no doubt be obtained as to the manner in which the grinding process has been conducted, but no definite quantitative results are procurable by such rough-and-ready methods, useful though they may be in their own place up to a certain point.

There is little room for doubt that the peculiar texture and freedom from all feeling of grit which one is accustomed to associate with finely ground pigment is due to two factors—(1) the small size of the particles of pigment in the paint, (2) the uniformity in the size of these particles. In other words, the more nearly the particles approximate to one uniform size and the smaller this size is, the more perfectly will the product fulfil the description of a finely ground paint.

At first sight it might be expected that after a sample of paint had been passed once, twice, or thrice through an efficient grinding mill the particles of pigment would become reduced to an approximately uniform size. Such, however, does not appear to be the case. A practical limit appears to be reached after which no material increase in the physical fineness of the pigment takes place. This limit can be exceeded only at an unremunerative expenditure of power and time.

The general form of pigmentary particles can be observed under the microscope, which is a necessary adjunct to every well-ordered paint laboratory. The shape and appearance of many commonly used paint pigments are so characteristic that it is quite easy in many cases to detect qualitatively the component parts of a mixture of pigments by observation under the microscope. This is especially the case with the more crystalline pigments. It is obvious that the more nearly pigments approach to the perfectly spherical or, as it is

sometimes rather loosely termed, the amorphous state, the more difficult does their differentiation from each other by the aid of the microscope become.

The more finely ground or divided a pigment is the nearer do its particles approach in form to spheres, and, indeed, one may go so far as to say that when continued subdivision of a pigmentary particle results in the formation of smaller particles which are sensibly different from spheres the probability is that the material in question will have a limited range of usefulness as a pigmentary material. It is convenient in referring to the size of pigmentary particles, and in expressing it in terms of some selected unit, to take the mean diameter of the particle as a measure of its size, and in talking of the "size" of a pigment it is the *estimated mean diameter* which is indicated.

In the case of pigments which have been produced by the grinding of certain raw materials (e.g. native oxide of iron pigments, ochres, and the like), the particles exhibit immense variety in size, as might be expected. It is more surprising, however, to find that particles which have been produced more or less under control also vary in size through very wide limits. This is found to be the case with white-lead and many precipitated pigments. In this connection it is interesting to note the extreme uniformity in the size of the particles of oxide of zinc.

The longer that a pigment is subjected to efficient grinding the narrower will be the range between the smallest and the largest particles, the precise limits in any particular case depending on the nature of the pigment and on the amount of work put into it in the way of grinding.

When we proceed to grind a pigment we find that the larger particles are capable of being reduced to an approximately uniform size with comparative ease, but that when a certain point is reached further reduction is obtained with more difficulty. In other words, a limited amount of grinding effects a great reduction in the size of the particles at

first, but in order to remove the last trace of grit the operation must be repeated again and again. In this connection attention may be directed to the influence exercised by the construction of the grinding plant, the material of which the rollers are made and the like.

The actual measurement of pigmentary particles under the microscope opens up a field of interesting and useful work. Much confusion arises through measurements of pigmentary particles being stated by different writers in terms of different standards. Thus, one observer expresses his results in terms of inches, another in terms of millimetres, and so on. It would tend to simplicity and convenience if the metric system were adopted universally in this and other departments of scientific work, and, furthermore, in order to simplify the expression of results, the adoption of a definite unit in connection with the measurement of minute pigmentary particles is to be advocated. This unit, which represents the one-thousandth part of a millimetre, is termed the micro-millimetre, and is represented by the symbol μ .

If we adopt this unit we avoid the need for the procession of noughts after the decimal point which is so liable to lead to clerical error in transcribing results. The relations between the inch, the millimetre, and the micro-millimetre are as follows :—

$$\begin{aligned} 1 \text{ inch} &= 25.39954 \text{ mm.} \\ 1/1000\text{th or } .001 \text{ inch} &= .025.39954 \text{ mm.} \\ &= 25.39954 \mu. \\ \text{or say for ordinary calculations} &= 25.4 \mu. \end{aligned}$$

The following are measurements of various pigments by various observers expressed in terms of micro-millimetres. (μ) :—

E. J. MILLS.

Ground in Oil.			Estimated Average.
	Smallest.	Largest.	
Whitelead . .	1.725	14.800	5.934
Oxide of iron . .	3.450	16.525	7.762

R. S. PERRY.

Ground in Oil.		Smallest.	Largest.	Estimated Average.
Whitelead	. .	.610	6.600	1.800
China clay	. .	3.000	6.500	Not determined

J. CRUICKSHANK SMITH.

Dry Pigments.

Light Indian red	. .	4.176	12.700	6.350
Levigated French ochre		4.076	6.350	4.572
Deep purple brown	. .	5.080	8.458	6.350
Burnt Turkey umber		4.170	16.000	8.382
Whitelead	. .	6.112	7.023	6.412
China clay	. .	3.215	4.064	3.582

The method commonly adopted in determining the size of small pigmentary particles is to distribute the pigment as evenly as possible over a slide, which is then examined through a micrometer eyepiece, the scale in which is ruled in $\frac{1}{1000}$ ths of an inch. The particles occupying each division are then counted. This, if four particles fill one division, the average size of the particles is .00025 inch, which, multiplied by the factor 25.4, gives .00635 mm. or 6.35 μ . All measurements should be taken twenty times in order to obtain a reasonably accurate figure for the mean diameter.

In the measurement of pigmentary particles for the purpose of predicting the behaviour of the pigment when used as a paint material three separate figures are necessary:—

- (1) The mean diameter of the smallest particles ;
- (2) The mean diameter of the largest particles ;
- (3) The estimated mean diameter of all the particles.

It is obvious that the nearer (3) approaches to (1) the more perfect is the grinding of the pigment under observation.

Is it possible, it may be asked, to state with any degree of accuracy within what limits of size pigmentary particles should fall in order to enable the pigment to be described as

“finely ground” and to fulfil the conditions as to size of particles required in a protective paint?

From a survey of the published technical work on this subject, and from numerous independent observations which the author has made, the opinion is offered that a pigment or a paint may as a rule be regarded as finely ground:—

(1) When the mean diameter of the smallest particles does not exceed $5.0\ \mu$;

(2) When the mean diameter of the largest particles does not exceed $25.0\ \mu$;

(3) When the estimated mean diameter of all the particles does not exceed $10.0\ \mu$.

These figures refer more particularly to ordinary protective paints. In the case of enamel paints and materials of a similar nature the requirements as to fineness of grinding are much more stringent.

If we select some standard of size for pigmentary particles such as that just mentioned, and observe the time necessary to reduce the size of the particles composing different paints to this standard by grinding similar weights under uniform conditions, we obtain useful information as to the amount of work which has to be put into different paints in grinding them, and the information so obtained may be employed as a basis in apportioning various items of cost in the manufacture.

Spreading Power.—This term is restricted to paints which are ready for use. The proportion and nature of the liquid medium in such paints necessarily exerts a considerable influence on the spreading power: the less viscous a paint is the greater the area it will cover. But although the spreading power may be increased by the addition of thinning materials, there is a practical limit beyond which the thinning process cannot be continued. This limit is the point at which the paint ceases to exhibit one of the primary and essential properties of good paint—the point, namely, at

which opacity begins to diminish. Consequently, before it is accepted as a recommendation of a certain paint *A* that it spreads over, let us say, 10 per cent more area than another paint *B*, it is necessary to inquire whether the respective films of paint are comparable in other respects, and in particular whether they mask the surface equally well.

It has already been indicated that the paint-grinder frequently has it in his power to grind his paste-paints in such a manner as to influence more or less the spreading power of the paint when thinned for use. One of the chief factors in this matter is the fineness of the particles. A well-ground paint will always, *ceteris paribus*, cover better when thinned out than an imperfectly ground sample, even though the latter should be superior in other respects. It is a matter of frequent observation that paints which in staining power and opacity do not rise beyond mediocrity often give the greatest satisfaction to persons using them, simply because they flow easily and spread well under the brush.

The area over which a definite volume of a given paint will spread when applied by the brush depends mainly on —(1) the composition and physical texture of the pigment base; (2) the composition and proportion of the medium; (3) the nature of the surface; (4) the brush or tool employed; and (5) the manner in which the latter is used.

It will be seen therefore that there is extreme difficulty in arriving at figures which are strictly comparable. The subject has already been discussed in Chapters XII. and XIII.

CHAPTER XVI.

ECONOMIC AND GENERAL CONSIDERATIONS.

Cost Charges.—In any industry the manufacturer who is able to make an exact estimate of the cost of producing the finished article is in a favourable position for encountering commercial fluctuations, and for dealing advantageously with sudden changes of price. In the case of industries which deal with a single product or with a limited range of products manufactured in the same manner, and in which the operations are performed wholly by machinery, there is rarely any difficulty in calculating the exact cost per unit of finished work. A textile factory containing hundreds of machines of uniform construction, each attended by workers earning the same standard rate of wages, while the output is determined entirely by the known mechanical capacity of the machines, affords an example of this. The calculation of manufacturing cost in such a case is quite simple. In the event of the workers' wages being advanced, say, one-eighth of a penny per hour, the corresponding increase in the cost of production can easily be expressed per unit of finished work. Again, if a machine is introduced which will turn out 20 per cent more work in a given time, the manufacturer can readily calculate the extent to which the cost of manufacture will be affected.

In the manufacture of paint the case is altogether different. Notwithstanding the great change which has taken place, especially during the last twenty years, in the construction of paint plant and machinery, the output continues to be regulated less by the machine than by the man. There is no exaggeration in saying that the output from two

similar mills in the hands of different workmen may vary to the extent of 50 per cent. The "personal equation" therefore counts for much in paint manufacture.

For the purposes connected with "costing," manufacturing businesses may be divided into two classes; (1) those in which the operations partake of the nature of construction, such as engineers, vehicle builders, furniture manufacturers, and textile manufacturers; (2) those in which the manufacture is by process. To the latter group belong all the chemical industries, including the manufacture of paint, and in these the calculation of cost is much more difficult than in the case of the first mentioned group. No system of costing can be set out for manufacture by process without special reference to the individual business.

The systematic framing of manufacturing costs in the paint industry was undoubtedly neglected in the first instance owing to the profits having originally been very considerable. With increased competition and lower selling prices manufacturers have been obliged to consider the question more carefully. The ordinary trade selling price of some paints shows a much greater margin of profit than is the case with others. Every paint manufacturer knows how carefully and economically work must be conducted in order that the grinding of whitelead and a few of what may be termed heavy lines, e.g. driers, putty and oxide paints, may show a working profit. It is true that these are the paints which as a rule are turned out in the largest quantity, a circumstance which tends to equalize matters; at the same time, they are also lines in which the keenest cutting takes place in the price.

Whatever system of calculating costs is adopted, the peculiarities of the trade must be taken into account, and two points that must not be lost sight of are, first, the mutual relationship of man and machine, and, second, the variation in time per unit of output in the case of different products.

The charge for labour, that is the wages paid in connection with the actual manufacturing process, but exclusive of general supervision and management, falls to be considered first.

The variation in the output of different paints in equal spaces of time, and under otherwise similar conditions, has been employed with success as the basis of a system of paint-grinding costs. As an example of the method of applying such a system, we will suppose that it is known from verified data that in a ten hours' working day a plant fed and worked by three men, earning respectively x , y , and z shillings per day, will turn out 100 cwt. of ground whitelead, or 50 cwt. of ground oxide of zinc, or 50 cwt. of common oxide of iron paint (ground once), or 30 cwt. of fine oxide of iron paint (ground twice), or 10 cwt. of fine staining colour, e.g. sienna (ground three times). The cost of labour per ton will consequently, on the basis of the above-mentioned figures, be as follows:—

Labour on whitelead	.	per ton	=	$\frac{x+y+z}{5}$	shillings.
„ oxide of zinc	.	„	=	$\frac{2}{5}(x+y+z)$	„
„ common iron oxides	„		=	$\frac{2}{5}(x+y+z)$	„
„ fine iron oxides	„		=	$\frac{2}{3}(x+y+z)$	„
„ fine stainers	.	„	=	$2(x+y+z)$	„

And the *relative cost* for labour will obviously be—

Whitelead	.	.	.	.	.	1
Oxide of zinc	.	.	.	.	.	2
Common iron oxides (ground once)	.	.	.	.	.	2
Fine iron oxides (ground twice)	.	.	.	.	.	3.3
Fine staining colours (ground three times)	.	.	.	.	.	10

It is essential in making such a comparison that the different paints be placed on exactly equal terms. Thus, to

arrive at a true comparison, the same plant and the same men should be employed during the trials. A difficulty may arise in the case of an old factory irregularly laid down and containing mills of various types and capacities. In such a case it is best, when the necessary data are available, to compare the total output in the main classes of paint of all the mills taken together, treating each single mill merely as an element of plant. The result, though not free from error, will be sufficiently correct for practical purposes. By inserting values for x , y and z in the examples given, according to the current rate of paint-grinders' wages, exact expressions will be obtained (on the basis of the assumed output) for the cost of labour per ton of the various paints. Thus if $x = 5s.$, $y = 4s.$, and $z = 3s.$, the charge per ton for labour will be:—

	s.	d.
Whitelead	2	5
Oxide of zinc	4	10
Common oxides (ground once)	4	10
Fine oxides (ground twice)	8	0
Fine staining pigments (ground three times)	24	0

Individual manufacturers may find these figures to be over or under their estimated costs, according to the conditions that obtain in their works. Thus z becomes $\frac{z}{2}$ if the time of the third workman is equally divided between two mills. When only two men are required, then $z = 0$, and the charge per ton for labour will be still further reduced.

A distinction must always be made between *productive labour* (that is labour directly connected with the output of the finished product) and *unproductive labour* due to the employment of odd men whose cost cannot be assigned to any one product. Labour which ought to be productive readily becomes unproductive through bad time-keeping, waste of time during working hours, and especially through

inefficient or careless supervision. Every penny spent on labour must be accounted for somewhere in the costing system, and there is a tendency to omit to check these unproductive labour charges when a figure representing cost of labour has once been adopted as a fixed charge on each unit of output. The total wages bill should therefore be scrutinized from time to time and any amount unaccounted for must be distributed as an overhead cost on the whole of the output of the works.

Cost of Handling.—The charges involved in conveying the raw materials and the manufactured goods from one part of the works to another, in putting them into and taking them out of store, in filling small packages from bulk, in labelling, packing, etc., are included under this heading.

Carriage and Delivery of Goods.—This is clearly an item of cost which can be dealt with best on the basis of tabulated details as to the tonnage conveyed and the area of distribution. Under modern conditions this item is not likely to decrease. Goods have to be sent out with greater expedition and in smaller consignments than formerly, and competition compels manufacturers and merchants to pay carriage in cases where at one time this charge would have been defrayed by the buyer. There is every indication also that the levelling up of economic conditions on the railways will not conduce to the lowering of railway rates. Elaborate statistics have shown that taking a variety of industries the cost of freight to the average distance of destination is on the average 6 per cent of the value of the goods. So far as figures are available it would appear that from 3 to 5 per cent on the sale value is the average cost of delivery and carriage of the output from an average paint factory which supplies the usual range of materials to a variety of customers.

Cost of Materials.—The cost of materials should be kept totally distinct from all other costs, and should be so ex-

pressed that variations in the price or value of one or more of the raw materials can be easily dealt with. Linseed oil is a material that demands particular attention in this respect on account of the daily fluctuations in its value. The following indicates a simple method of expressing the cost of materials in the case of an ordinary oxide of iron paint:—

	s.	d.
3 cwt. dry oxide of iron at 6s. per cwt.	18	0
2 qrs. 7 lb. linseed oil at 24s. per cwt.	13	6

Materials cost per ton £8 16s. 10d.

1 ton of paint contains 3 cwt. 18 lb. of
linseed oil.

Variation in cost per ton of paint for
every 20s. per ton difference in
price of oil, 3s. 2d.

In the case of a formula which includes materials which are themselves products of manufacture at the works a system of “costs within costs” must be followed, the direct charges incurred in manufacturing such materials being included in their cost as entered in the formula. Thus if chrome yellow or a special mixing varnish which has been manufactured on the premises is an item in the formula it should be entered at its “all in” cost and not at its cost for materials only.

There is an item of cost which is not always sufficiently noted, namely the waste or loss that takes place, sometimes unavoidably, in weighing or measuring raw materials and through handling, etc. In well-ordered works loss through causes of this kind is reduced to a minimum, but unfortunately the appearance of some paint factories encourages the prevalent idea that the manufacture of paint is of necessity a dirty and haphazard operation. Such need not be the case; and just as in many other industries the prevention of waste and the utilization of by-products are among the most fruitful sources of profit, so in the manufacture of paints conveniently arranged premises, accurate weighing of the

charges, clean working, a minimum amount of handling, and efficient supervision will be found to have not a little influence in diminishing the cost of manufacture. In working with volatile materials, such as turpentine, methylated spirit, naphtha and the like, the loss which is unavoidable should be determined with as great accuracy as possible, after which allowance can be made for such loss in estimating the cost of working.

In addition to losses in raw material there are opportunities for losses also in connection with the finished products. Tons of paint can be wasted in the course of a year through slovenly working and careless weighing or measuring into small packages. The use of mechanical fillers for liquid goods is to be recommended in this connection.

Machinery as affecting Manufacturing Cost.—The influence of machinery on cost of production is almost too obvious to call for remark. A few points, however, are apt to be lost sight of. During the last few years paint plant has increased enormously in variety, in power and in weight. Heavy plant has become the order of the day. Efficient grinding depends on the amount of friction produced between the grinding surfaces *during the passage of the material*. Many mills are met with, however, which absorb an excessive amount of power when no grinding is in progress. As much as 25 per cent of the power of an engine has been known to be consumed in overcoming the friction of the machinery and plant running light. By judiciously selecting well-constructed plant, and by keeping all running parts in thorough repair, this waste can often be avoided or reduced, and the charge on account of power will then show a marked reduction.

If a steam engine is used much valuable information can be obtained by having it "indicated". The indicator diagrams show graphically the variation in the internal pressure in the cylinder at all points of the stroke under different loads. The actual indicated h.p. absorbed in overcoming

friction, or necessary to drive a mill grinding or mixing a particular paint, can also be calculated, and the results may be employed to check or correct the charge per ton on such paint on account of the item of power.

As labour-saving machinery becomes more general the charge on account of manual labour will necessarily be reduced. In order that full advantage may be derived from the machinery it is necessary to ensure that the maximum output is secured from each machine or set of machines. No machinery will work entirely automatically, and the workman always has it in his power to curtail the output under the mistaken idea that by diminishing the output he is providing more work and consequently more wages for his class. He will no doubt in course of time see that it is not by increasing the cost of production to the manufacturer that this end will in the long run be achieved. It is very desirable to prevent such tactics on the part of those controlling machinery, by giving them a direct incentive to increase the output and at the same time to preserve a high and uniform quality in the goods turned out.

Electricity as Motive Power.—A noteworthy increase has taken place during the last ten years in the use of electricity as the motive power in paint factories. This is due in a great measure to the fact which has already been alluded to, namely the diverse and intermittent nature of many of the operations of paint manufacture. The whole manufacture takes place in stages, and very often these do not proceed concurrently. Hence although on theoretical grounds a steam engine ought to be the cheapest form of motive power, it may not be so in practice unless every machine is working at its full capacity all the time.

Driving the machinery by electric motors has therefore become exceedingly common, and an impetus has been given to the system by the low rates at which electricity for power purposes can now be purchased in many districts.

There is a tendency in modern factory design to use machinery units of large size, and the most efficient way to drive these is by means of a separate motor geared to each machine. It happens not infrequently that such machines may have to stand idle from time to time. This means, if several machines are driven by one motor, that for long periods the motor is not running at maximum efficiency, and that a constant load of shafting is always running, although it is rarely fully loaded.

The cost of driving the shaft of a particular machine in the course of a fifty-four hour week will often represent a large proportion of the power taken by the machine during the number of hours that it is running with a working load. This proportion, when worked out, is always much larger than appears at first sight. For instance, suppose that a certain wheel requires 9 h.p. to drive it, and that the shafting for the same wheel requires 1 h.p. It would appear that the actual loss by driving through this shafting was 10 per cent; but suppose that the machine only works twenty-seven hours and the shafting fifty-four, then the machine will consume 243 h.p. hours and the shafting fifty-four. In other words there is a loss of 33.1-3 per cent. A saving of one-third in the cost of current will very soon repay the additional cost for a separate motor to drive the mill.

Where small units are employed, the capital outlay for a separate motor to each machine is sometimes an obstacle, and then one motor may be installed to drive a gang of machines by means of a line of shafting. When this is done, care should be taken in handling the plant not to start all the machines to break up or "pug" raw material at the same time, as the power then consumed is very much greater than when the material has been mixed for a little time by the mills. The machines should be started upon the raw material in rotation; by this means a smaller motor can be employed in the first place, and this machine will be kept running at a higher efficiency. A powerful "combination"

mixing and grinding plant which required 12-15 h.p. to drive it under normal conditions has been known to take 25 h.p. at the beginning of the mixing process when the raw material was carelessly fed in.

The importance of cleanliness cannot be too strongly insisted upon, and it is not advisable to fix motors in pits or any place where dirt or moisture is likely to collect. It is preferable, whenever possible, to have the motors fitted upon galleries or brackets away from the floor.

The cost of upkeep of electric plant is less than that of any other prime mover, provided that regular inspection is given and small adjustments made as soon as they are required.

In places where dry dust is in the atmosphere, the motors should be totally enclosed. A convenient form of totally enclosed motor has been recently introduced by Messrs. Marryat & Place in which the motor is provided with a fan which draws a current of clean air by means of a tube. This air ventilates the motor, and prevents any undue rise in temperature. By the courtesy of Messrs. Marryat & Place, who are specialists in electrical engineering in connection with paint factories, the illustrations (Figs. 73, 74) on pp. 215 and 216 include electric motors of this type.

In places where there are any acid fumes in the air, the motors should be specially protected by means of acid-proof enamels from deterioration by the acid. In this connection it may be noted that the enamel used on the windings of the motors must be sufficiently elastic to withstand variations of temperature and must not get brittle, otherwise it will find its way on to the armature surface by centrifugal force.

When a number of separate motors are employed it is an advantage to have each one fitted with an ammeter by means of which the average power consumed can be checked. Violent fluctuations in the ammeter reading indicate that the load is not regular, and careless feeding of the charge is usually the cause of this.

Knowing the average ampere reading on the ammeter of a particular machine we can readily calculate the h.p., one ampere being equivalent to .558 h.p. If we multiply the average ampere reading by the average voltage of the current and divide by 1000 we obtain the number of Board of Trade units per hour (kilowatts).

$$\frac{\text{Amperes} \times \text{volts}}{1000} = \text{units per hour (kilowatts)}.$$

Thus if the current costs 1d. per unit, the number of kilowatts $\times 1$ = pence per hour which the machine is costing for current. The practical importance of being able to calculate the power required by different machines when dealing with various paints cannot be exaggerated, and the figures obtained in this way are a valuable aid in calculating manufacturing costs.

Two points should always be borne in mind in connection with selecting a motor for paint works. The first is that the power required by a particular machine may vary by as much as 100 per cent according to the class of material which is being dealt with and the skill and care displayed by the workman who operates the machine. The second point (which arises out of the first) is that there should be an ample limit between the rated h.p. of the motor and the highest h.p. which is expected to be required in working.

Manufacturing Oncost.—With regard to the remaining charges which fall to be apportioned on the manufactured goods and which include rent, rates, lighting, management, etc., and which are usually described in the technical phraseology of accounting as “oncost” the simplest and most correct mode of dealing with them is best arrived at after laying all the facts of the case before a professional accountant.

Prices.—The relation of prime cost to selling price in

products of the paint industry cannot be expressed in general terms.

To formulate general rules on the subject would be attended with more difficulty than would occur in perhaps any other manufacturing industry of equal magnitude. Among the causes contributing to this, one of the chief is the great variety in the classes of buyers of the manufactured articles, each buyer having his own methods, ideas and sometimes prejudices, so that the price paid by one class would often not be paid by another. Another reason is that paint is a material of arbitrary composition and there is no fixed standard of quality. Hence paints of widely different composition may be referred to by the same general trade-name. Even in the case of so-called "pure" paints, e.g. pure burnt sienna in oil, pure native oxide of iron in oil, etc., the same remark holds good, because burnt sienna and native oxide of iron are examples of natural products the composition of which varies to a very great extent, with of course a corresponding variation in the intrinsic value of the pigments.

The Future of the Industry.—With the data at our disposal there is extreme difficulty in estimating even approximately the value of the paint manufactured annually in Great Britain. Official returns show that month by month large quantities of paints, varnishes, dry pigments and similar goods are sent out of the country, but for Board of Trade purposes these are all slumped together under the designation of "painters' materials" which also includes a considerable but unascertainable amount of raw material brought from abroad and then exported in the self-same condition in which it arrived. Thus we have no means of estimating separately the paint manufactured for export and the paint materials imported with a view to immediate re-exportation. Equally difficult is it to estimate with any degree of exactness the value of the enormous quantity of paint manufactured for home consumption. The imports of raw material would

supply some clue to the extent and fluctuations of the industry as a whole, but for the circumstance already mentioned that a portion of this material which cannot be determined leaves the country without undergoing any change. This much may be said, that the sale value of paints manufactured in Britain is considerably more than is generally suspected and that it is not decreasing from year to year. On the contrary there are indications that the volume of the trade has been steadily increasing.

When we direct our attention seriously to the probable future of this industry we are confronted by two outstanding considerations. On one hand, signs are not wanting that the field for the use of paint at home and abroad, both for decorative and protective purposes, appears to be enlarging and tending to enlarge. There is the prospect of a growing demand for paint in connection with dwellings and business premises and public institutions and engineering structures and railways and shipping and the innumerable surfaces of various kinds which are usually coated with some sort of colour for purposes of utility or of taste.

A noteworthy change has taken place in the attitude of the public towards paint and allied products during the last decade. The property owner and the householder concern themselves more in the protection and decoration of their property than formerly. Paint has therefore become a matter of public interest, just as it has been in America for many years past. Painters and decorators used to be to all intents and purposes the sole or at any rate the chief purchasers of paint. This is no longer the case, and at the present time a very large proportion of the paint manufactured in Britain is not sold to painters and decorators at all. Whether this is a good thing or the reverse is a question which can be argued, and it is not our province to discuss the matter here. Nevertheless it is futile to blind ourselves to the fact that in matters concerning protective paints especially the public have begun to act as their

own advisers, and that their tastes have to be consulted.

The other consideration is one which affects the paint manufacturer very intimately. It is that while selling prices have not advanced and have in very many cases decreased seriously owing to that competition which is both inevitable and stimulating, the costs incidental to the processes of manufacturing and marketing the finished product have been steadily advancing. Raw materials are dearer, coal is dearer, the cost of labour has advanced, imperial and local government restrictions have made manufacturing processes more expensive, on all sides costs have increased, and, what is sometimes lost sight of, the outlay required to market the finished goods is considerably higher now than it used to, nor is there any likelihood that it will decrease.

In every department of his business, therefore, the modern paint manufacturer will have to be alert and watchful. The stigma which for so long rested on the manufacture of paint that it was a secret, mysterious process trammelled by rule-of-thumb methods and imbued with a spirit antagonistic to science and progress has happily been removed, and the industry can to-day be regarded as not the least important among the scientifically guided industries of Britain. But the manufacturer who aims at continued success must still be anxiously careful in the selection and use of machinery, not trusting blindly to any installation, however excellent to begin with, for a lengthened period, but judiciously revising his mechanism from time to time. The strain of competition will make it more and more imperative to conduct the manufacture in all its details with the utmost skill and economy, and to aim at producing the article which the customer requires. The customer on his part should state his wants intelligently, and large consumers need have no difficulty in furnishing an exact specification of their requirements. Nothing is more desirable than honourable feeling and a good understanding between

manufacturers or merchants and customers, and the removal of any ground for the suggestion that one is taking advantage of the ignorance of the other.

It will well repay the manufacturer to make a study of the requirements of those who use his products, to get to know the conditions which govern the application of them, and so be in a position not only to turn out products which are in themselves commendable, but which are also specially adapted for the purposes for which they are likely to be employed.

THE END.

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